GUYANA

INITIAL NATIONAL COMMUNICATION

IN RESPONSE TO ITS COMMITMENTS TO THE UNFCCC

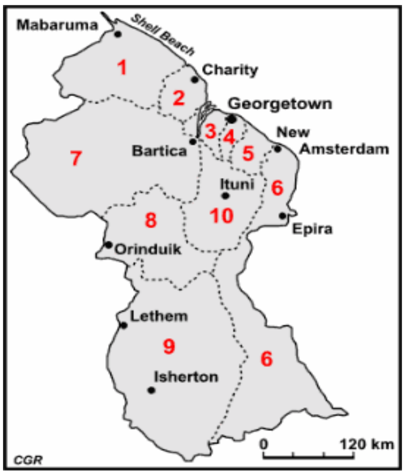
NATIONAL CIRCUMSTANCES

GREENHOUSE GAS INVENTORY

VULNERABILITY AND ADAPTATION

MITIGATION ANALYSIS

MONITORING AND UNDERSTANDING CLIMATE CHANGE AND IMPACTS



April 2002

A C K N O W L E D G E M E N T S

Funding for the preparation of this Initial Communication was provided by the Global Environment Facility through the UNDP, their support is acknowledged.

The International Consultant, Professor Bhawan Singh, and his team provided many guidance documents and participated as key resource persons at the Workshops and Working Group Meetings. Their contribution is recognized.

The Office of the President, the Natural Resources and Environment Advisory Committee and the National Climate Committee provided valuable support and played a major role in the completion of this Initial Communication.

The effort of the National Task Force, who developed and shaped the Communication, is also recognised.

TABLE OF CONTENTS

DATA SOURCES

4.0 NATIONAL INVENTORY OF GREENHOUSE GASES

1. Guyana Energy Agency, 295 Quamina Street, South Cummingsburg, Georgetown.
2. Guyana Forestry Commission, 1 Water St., Kingston, Georgetown.
3. Guyana Sugar Corporation Inc.
4. Ministry of Fisheries, Crops and Livestock. Regent and Vlissingen road.
5. Bureau of Statistics, Brickdam, Georgetown.
6. Guyana Oil Company Limited, 166 Waterloo Street, Georgetown.
7. Texaco West Indies Limited, Ramsburg, Providence, East Bank Demerara.
8. Esso Standard Oil S.A. Ltd., 126 Quamina St., South Cummingsburg.
9. Shell Antilles and Guianas Ltd., BB Rome Agricola, East Bank Demerara.
10. Mayor and City Council, Cleansing Section, Princess St., Georgetown.
11. National Dairy Development Programme, Durban Street.
12. Ministry of Agriculture, Regent and Vlissingen road.
13. Guyana Rice Development Board, Cowan Street, Kingston.
14. Dipcon Engineering Services Ltd. Coldingen.
15. Food and Agricultural Organization Yearbooks (1990 – 1997)
16. Revised 1996 IPCC Greenhouse Gas Inventory Workbooks
17. IPCC (1995) Greenhouse Gas Inventory Workbooks

ABBREVIATIONS

ASLR	Accelerated Sea Level Rise
A-OGCM	Atmosphere – Ocean General Circulation Model
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COP	Conference of Parties
CFC's	Chlorofluorocarbon
CARICOM	Caribbean Community
CPACC	Caribbean Planning for Adaptation to Climate Change
DBH	Diameter Breast Height
DOC	Degradable Organic Compounds
DSSAT	Decision Support System for Agro Technology Supply
DTR	Diurnal Temperature Range
ENSO	El Nino Southern Oscillation
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ET	Evapotranspiration
EST	Environmentally Sound Technology
FAO	Food and Agriculture Organisation
FDS	First Dry Season
FWS	First Wet Season
GDP	Gross Domestic Product
Gg	Gigagramme
GHG	Greenhouse gas
GIS	Geographic Information System
GCM	General Circulation Model
GD	Georgetown Datum
GHGM	Greenhouse Gas Mitigation
GEF	Global Environment Facility
GWP	Global Warming Potential
ICZM	Integrated Coastal Zone Management
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter-Tropical Convergence Zone
LPG	Liquefied Petroleum Gas
MACC	Mainstreaming Adaptation to Climate Change in the Caribbean
MSW	Municipal Solid Waste
MAGIC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MAAT	Mean Annual Air temperature
MTAP	Mean Total Annual Precipitation
NMVOC	Non-Methane Volatile Organic Compound
NO_X	Oxides of Nitrogen
N_2O	Nitrous Oxide

NCC	National Climate Committee
NRMP	Natural Resources Management Project
NREAC	Natural Resources and Environment Advisory Committee
NGO's	Non Governmental Organisations
NEEPAS	National Environment Education and Public Awareness Strategy
NBS	Net Basin Supply
O_3	Ozone
PSMSL	Permanent Service for Mean Sea Level
PER	Potential Evapotranspiration Ratio
SWDS	Solid Waste Disposal Sites
SDS	Second Dry Season
SWS	Second Wet Season
TJ	Terajoules
UNFCCC	United Nations Framework Convention on Climate Change
UNCED	United Nations Conference on Environment and Development
UV	Ultra-Violet
WMO	World Meteorological Organisation

A GLOSSARY OF KEY TERMS

Adaptation

The adjustment of an organism or population to a new or altered environment. Also refers to conscious and unconscious decisions made by people to adjust to changes, such as adaptation to climate change.

Alternative Energy

Energy derived from non-fossil fuel sources.

Anthropogenic Emissions

Emissions of greenhouse gases associated with human activities. These include burning of fossil fuels for energy, deforestation and land-use changes.

Atmosphere

The envelope of gases surrounding the earth and bound to it by the earth's gravitational attraction.

Biomass

The total dry organic matter or stored energy content of living organisms. Biomass can be used for fuel directly by burning it (e.g. wood), indirectly by fermentation to an alcohol (e.g. sugar) or extraction of combustible oils (e.g. soybeans).

Capacity Building

A process of constructive interaction between developing countries and the private sector to help them develop the capability and skills needed to achieve environmentally sound forms of economic development. The process makes use of the private sector's modern technologies and management systems, in combination with a competent workforce and appropriate laws and regulations.

Carbon Dioxide (CO_2)

A naturally occurring gas, it is also a by-product of burning fossil fuels and biomass, as well as land use changes and other industrial processes. It is the principal anthropogenic greenhouse gas that affects the earth's temperature.

Carbon Dioxide Fertilization

Enhancement of plant growth or yield as a result of an increase in the anthropogenic concentration of CO_2.

Carbon Sequestration

The long-term storage of carbon or carbon dioxide in the forests, soils, ocean, or underground in depleted oil and gas reservoirs, coal, seams, and saline aquifers.

Carbon Sinks

Natural or man-made systems that absorb carbon dioxide from the atmosphere and store them. Trees, plants, and the oceans all absorb CO_2 and are examples of carbon sinks.

Climate

The climate may be described as the statistical description of weather and atmospheric conditions as exhibited in extremes, averages, and variables of temperature, precipitation, wind and other related atmospheric elements, including patterns of such conditions, globally or in a given region, over a specified period long enough to be representative (usually a number of decades).

Climate Change *(UNFCCC definition)*

A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods.

Climate Models

Large and complex computer programmes used to mathematically simulate global climate. They are based on mathematical equations that seek to present the physical processes that govern the earth atmosphere system.

Climate System

The totality of the atmosphere, hydrosphere, biosphere, and geosphere and their interactions.

Cogeneration

The use of waste heat from electricity generation, such as exhaust from gas turbines, for either industrial purposes or district heating.

Conference of the Parties, or COP

The supreme body of the UNFCCC, comprised of countries that have ratified or acceded to the framework Convention on Climate Change.

Ecosystem

The interacting system of a biological community and its non-living environmental surroundings.

El Nino/La Nina/ ENSO

At irregular intervals, but on average about every four years, widespread warming of the east-central equatorial Pacific sea surface temperature occurs. This warming, which typically lasts for about a year, is called EL Nino event. El Nino can be regarded as the warm phase of a major climate oscillation. During the cold phase, called La Nina, the equatorial Pacific sea surface temperature is cooler than normal. The sea surface temperatures are associated with widespread atmospheric shifts in winds, rainfall etc.

Emissions *(UNFCCC definition)*

The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time.

Emissions Trading

A market-based approach to achieve environmental objectives that allows those emitters of greenhouse gas (GHG) to trade the excess emissions at another source inside or outside of the country that produced the emission. In general trading can occur at the domestic, international and intra-company levels. Article 17 of the Kyoto Protocol, allows Annex B countries to exchange emissions obligations.

Fossil Fuels

Carbon-based fuels, including coal, oil and natural gas.

Fuel Switching

Supplying energy by using alternative fuels. Often used to refer to actions that reduce CO_2 emissions from electric utilities by switching from coal to natural gas.

General Circulation Models, or GCMs

Large and complex computer programmes that attempt to mathematically simulate global climate. They are based on mathematical equations that seek to represent the physical processes that govern the earth-atmosphere system.

Global Environment Facility, or GEF

A joint funding programme established by developed countries to meet their obligations under various international environmental treaties.

Global Warming

The view that the earth's temperature is being increased, in part, due to emissions of greenhouse gases associated with human activities, such as burning fossil fuels, bio-mass burning, cement manufacture etc.

Global Warming Potential, or GWP

A time dependent index to compare the radiative forcing, on a mass basis, of an impulse of a specific greenhouse gas relative to that of CO_2. For example, methane has a radiative forcing that was estimated over a 100-year period to be 21 times greater than that of CO_2, thus it has a GWP of 21.

Greenhouse Effect

The trapping of heat by naturally occurring heat-retaining atmospheric gases (water vapour, carbon dioxide, nitrous oxide, methane and ozone) that keeps the earth at about 30 ^{o}C (86^{o} F) warmer than if these gases did not exist.

Greenhouse Gases, or GHGs

Gases in the earth's atmosphere that absorb and re-emit infra-red radiation. These gases occur through both natural and human-influenced processes. The major GHG is water vapour. Other GHGs include carbon dioxide, nitrous oxide, methane, ozone, and CFCs.

Gross Domestic Product, or GDP

The total value of goods produced and services provided in a country in one year.

Humidity

The degree of moisture in the atmosphere.

Impact Models

Computer programmes used to estimate the impact of specific climate change on natural, social or economic systems.

Intergovernmental Panel on Climate Change, or IPCC

Panel established in 1988, by governments under the auspices of the World Meteorological Organisation and the UN Environment Programme. It prepares assessment, reports and guidelines on the science of climate change, its potential environmental, economic and social impacts, technological developments, possible national and international responses to climate change and cross-cutting issues.

Kyoto Protocol

The Protocol, drafted during the Berlin mandate process, that, on entry into force, would require countries listed in Annex B (developed countries) to meet differential reductions targets for their greenhouse gas emissions relative to 1990 levels by 2008-12.

Laterite

A red or yellow ferruginous clay, friable and hardening in air, used for making roads in tropics.

Lithosphere

The rigid outer part of the earth consisting of the crust and upper mantle.

Methane, or CH_4

One of the six greenhouse gas included under the Kyoto Protocol, it has a relatively short lifetime of 10(+ or -) 2 years. Primary sources of methane are landfills, coal mines, paddy fields, natural gas systems and livestock.

Methane Recovery

Method by which methane emissions, from for example coal mines or waste sites, are captured and then re-used either through cost-effective measurement methods or through power generation.

Montreal Protocol

International agreement under the UN which entered into force in January 1989 to phase-out the use of ozone depleting compounds such as CFCs and methyl chloroform

Nitrous Oxide (N_2O)

One of the six greenhouse gases to be curbed under the Protocol, it is generated by burning fossil fuels and in the manufacture of fertilizer.

Non-Annex 1 Parties

The countries that ratified or acceded to the UNFCCC which are not included in Annex 1 of the Convention.

No Regrets

Actions that result in greenhouse gas limitations and abatement, and which also make good environmental and economic sense in their own rights.

Ozone

Ozone (O_3) is a greenhouse gas. In the atmosphere, or lower part of the atmosphere, ozone can be a constituent of smog. It is created naturally and also by reactions in the atmosphere involving gases resulting from human activities, including nitrogen oxides (NO_x) from motor vehicles and power plants.

Plateau (x)

An area of fairly level ground

Radiative Forcing

A change in the balance between incoming solar radiation and out-going infra-red and short-wave radiation.

Renewables

Energy sources that are constantly renewed by natural process. These include non-carbon technologies such as solar energy, hydropower, and wind as well as technologies based on bio-mass.

Reservoir

A component or components of the climate system where a greenhouse gas or a precursor of a greenhouse gas is stored (UNFCCC definition). The oceans, soils and forests are all carbon reservoirs.

Sinks *(UNFCCC Definition)*

Any process, activity or mechanism that removes a greenhouse gas or a precursor from the atmosphere.

Source *(UNFCCC Definition)*

Any process, activity that releases a greenhouse gas or a precursor from the atmosphere.

Trace Gas

This is a minor constituent of the atmosphere. The most important trace gases contributing to the greenhouse effect are carbon dioxide, ozone, methane, nitrous oxide, carbon monoxide, CFCs, HFCs etc.

UN Environment Programme, or UNEP

This U.N. Specialized Agency, established in 1972, to coordinate the environmental activities of the UN. It aims to help reinforce and integrate the large number of separate environmental efforts by Inter-governmental, non-governmental, national and regional bodies. UNEP has fostered the development of the UNFCCC and the Convention on Biological Diversity.

UN Framework Convention on Climate Change, or UNFCCC

A treaty signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries. Its ultimate objective is the “stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system.

CHAPTER ONE

EXECUTIVE SUMMARY

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Guyana signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development (UNCED) which was held in Rio de Janeiro in June 1992. The Convention entered into force for Guyana on November 17, 1994. Guyana, being a Non-Annex 1 and Non-Annex 2 Party to the Convention, prepared its Initial National Communication under the Guidance of Decision 10/CP.2 and Articles 4.1 and 12.1 of the Convention. An Enabling Activity Project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Development Programme (UNDP) called for the preparation of an Initial National Communication and a National Action Plan to address climate change and its adverse impacts. The Action Plan will be a supplement to the Initial Communication.

The National Climate Committee (NCC), comprising several governmental agencies, the University of Guyana (UG) and the Guyana Manufacturers Association (GMA), established a National Task Force that prepared the Initial National Communication and the Action Plan under the guidance of an international consultancy. Several Workshops and working group and Task Force meetings were held in order to train local resource personnel, and to prepare the several chapters of the two reports. The base year for this communication is 1994.

1.2 NATIONAL CIRCUMSTANCES 1994

Guyana is a tropical country situated on the northeastern coast of South America. It is bounded on the north by the Atlantic Ocean, on the east by Suriname, on the south by Brazil and on the west by Venezuela. It is an English-speaking country with close ties with the English-speaking Caribbean Islands. It is a member of the Caribbean Community (CARICOM) which has its headquarters in Georgetown, the capital city.

Guyana has the following characteristics:

- It is a low-lying state with a vulnerable coastal strip 77 km wide in the east and 26 km wide in the western Essequibo region.

- Ninety percent (90 %) of the population resides in the coastal strip where the main urban centres and commercial activities are to be found.

- There is a wide range of geographic types with coastal, hilly sandy, highland, forested and savannah regions.

- There is no current tectonic activity in Guyana and indications are that the Guyana shield (and the coastal strip, in particular) will not be affected by convergence of the South and North American plates.

- There is a high level of rainfall variability in the country and the seasons and climate are determined mainly by this variability. There are two wet and two dry seasons.

  First Dry Season (February to April);
  First Wet Season (April to July)
  Second Dry Season (July to November); and the
  Second Wet Season (November to January)

  The country can be divided into climatic regions ranging from dry (annual rainfall less than 1788 mm) to extremely wet (annual rainfall greater than 4100 mm).

- The major weather system is the Inter-tropical Convergence Zone and the major climate system is the El Niño Southern Oscillation (ENSO). Large-scale floods and droughts are as a consequence of the

ENSO events impacting on Guyana's weather.

Guyana was a British colony prior to its independence on May 26, 1966. The population is approximately 750,000 and comprises five major ethnic groups: East Indian, Africans, Amerindians, Chinese and Portuguese. There is a land area of 216,000 km^2 and a very low population density of about four persons per km^2. The major religions are Christianity, Hinduism and Islam.

With a Gross Domestic Product (GDP) per capita of US$ 528 in 1990, the economy grew, as a consequence of structural adjustment measures, by 8.5 % in 1994. The positive growth rate was primarily due to the effects of price liberalization, market-determined exchange rate and the positive results of private sector investments in the gold, timber and rice industries.

Agriculture is the major economic activity in Guyana. In 1994, this sector increased by 11.2 % compared to 5.4 % in 1993. This was due to recovery of sugar output and expansion of rice, timber and other crop production. The forestry sector was influenced by new governmental policies which facilitated significant foreign investment. The fishing industry experienced an increase in production by 7 %. The manufacturing, services, construction, mining, (and quarrying) sectors also contributed to the healthy growth rate in 1994. Tourism, in the form of eco-tourism, has been expanding and is expected to be a major contributor to the economy in the future.

Guyana is very dependent on imports of fossil fuels for its energy needs. Fuel and lubricants accounted for 16 percent of total imports in 1994. Bagasse is used for the co-generation of steam and electricity in the sugar and rice industries. There is the potential for substantial use of renewable energy sources such as hydropower, solar, wind and biomass.

The preparation of Guyana's National Greenhouse Gas (GHG) Inventory for 1994 showed that Guyana was not sufficiently strong institutionally, to address its commitments under the UNFCCC. There is the need to address capacity building in the government (including local government), the sector agencies and the private sector. The establishment of a Climate Unit with adequate staffing will allow for effective coordination of climate change activities.

1.3 NATIONAL INVENTORY OF GREENHOUSE GASES

As required by the Second Conference of Parties (COP 2) the GHG inventory for Guyana encompasses the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emissions of the indirect GHGs such as carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOC) are reported as well. The emissions of these gases are grouped into sectors according to the Inter-governmental Panel on Climate Change (IPCC) Guidelines, as follows: *Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste.*

The IPCC Revised 1996 Guidelines was used by Guyana to develop the inventory for 1994 with data for other years being used to indicate trends. CO_2 emissions from *international bunkers* and *bio-mass* are not included in the national totals but are reported separately as other sources of emissions.

In summary, the national inventory revealed that Guyana is a Net Sink country for CO_2 where removals (26,664 Gg) greatly exceed emissions (1446 Gg), that is, a removal balance of 25, 218 Gg in the base year 1994. The Energy sector (fuel combustion activities) is the major emitter of CO_2 having CO_2 emissions of 1446 Gg in 1994, while the Land Use Change and Forestry sector is the major sink for CO_2, with net removal/sink of 26,664.47 Gg in 1994, refer to table 1.1.

It also revealed in the inventory that CO_2 is the major GHG being emitted, which accounted for 96.5 % (1446 Gg) of the total emissions of CO_2, CH_4 and N_2O in 1994.

1.0 EXECUTIVE SUMMARY

TABLE 1.1: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1994.

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Total National Emissions and (Removals)	**1446** (-26,664)	**51**	**1**	**17**	**208**	**23**
1 All Energy	**1446**	**1**		**11**	**45**	**6**
A Fuel Combustion	1446	1		11	45	6
1 Energy Industry	602			3	9	
2 Industry (Manufacturing)	191			1	3	
3 Transport	203			2	22	4
4 Other Sectors (commercial, residential, agri. etc.).	450			6	10	1
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**16**
A Mineral Products (asphalt use on road)	NO	NO	NO	NO	NO	10
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		**41**	**1**	**4**	**95**	
A Enteric Fermentation		14				
B Manure Management		1				
C Rice Cultivation		22				
D Agricultural soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	67	
5 Land-Use Change and Forestry (a)	**-26664**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-29195					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Landfill		1				
Memo Items (b)						
(i) International Bunkers, total	**28**					
- Aviation	24					
- Marine	4					
(ii) Biomass Emissions	**1200**					

Key: 1. (NO) - Not occurring
2. (NE) - Not estimated
3. (NA) – Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may

not represent the actual summing of values in the sub-headings of the table.

The Agriculture sector is the major source of CH_4 and N_2O emissions, with emissions totaling 51 Gg and 1 Gg respectively in 1994. Under this sector, rice cultivation and enteric fermentation in animals are the main sources of CH_4 while that of N_2O emissions are from the use of synthetic nitrogen fertilizer on agricultural soils.

As for the indirect GHG's, NO_x and NMVOC, the major source sectors are the Energy and Industrial Processes sectors respectively while CO seems to be having several main source sectors, Agriculture, Land Use Change and Forestry, and Energy, with Agriculture being the major sector for emissions of this GHG. See table 1.1 for emissions and direct sources of these greenhouse gases for the year 1994.

There are many data gaps that will have to be addressed in future inventories. GHG specific data collection in the Energy and other sectors will have to be done. Current data collection procedures are not adequate even to satisfy sector needs. Hence there is the need to address data collection as a national issue.

As a consequence of the crude estimations, which were made due to inadequate data, uncertainty exists in the inventory analysis. However, a greater uncertainty exists in applying default emission factors. In some cases, factors used in other countries were applied. This indicates that Guyana needs to develop the capacity to prepare emission factors for local conditions and not rely on defaults. This applies to all sectors and all GHGs.

1.4 IMPACTS AND VULNERABILITY ASSESSMENT

Climate Change and Sea Level Rise

While Guyana is a net sink country for greenhouse gases, it is most vulnerable to the impacts of climate change.

The records in Guyana suggest an increase by 1.0°C of the mean annual temperature in Georgetown over the period 1909 to 1998. Cooling periods in the record appear to be due to the influence of major volcanic eruptions in several parts of the world. Prior to 1960, annual rainfall amounts were generally above or about normal. From 1960 and onwards, there has been a tendency for below normal rainfall. ENSO events have severely affected Guyana especially in the last decade of the twentieth century.

The atmosphere-ocean global circulation model (A-OGCM) of the Canadian Climate Centre (CGCM 1) was used to develop predictions of rainfall, temperature, evaporation and water deficit for two scenarios of carbon concentration: doubling and tripling. For a doubling scenario, temperature is expected to rise by 1.2°C in the period 2020 to 2040 from present. Highest increases in excess of 1.5°C, are expected in southern Guyana in the Second Dry Season (August to October). Rainfall is expected to decrease by an average of 10 mm per month but the decrease in the First Wet Season and Second Dry Season (May to October) will be 12 mm per month or higher. Evaporation, however, appears to show insignificant increases (less than 3 mm per month). Water deficit will be about 8 mm per month on average with larger deficits in southern Guyana.

With a tripling of CO_2 concentration in the latter part of the twenty-first century, Guyana could experience a temperature rise of 4.2°C on average. Here again, southern Guyana may experience highest increases. Rainfall can decrease by an average of 21 mm per month with higher decreases in the First Wet Season (FWS) and Second Dry Season (SDS). Again, southern Guyana could be influenced by the highest decreases. Evaporation is likely to increase by about 3.3 mm per month. Here, however, it is northern Guyana, which may be affected by evaporation rates in excess of 12 mm per month. Southern Guyana may experience large water deficits in the First Wet Season and Second Dry Season while northern Guyana is likely to be affected by deficits in excess of 22 mm per month.

The Hadley Centre A-O GCM showed somewhat similar projections except that, for the tripling CO_2 scenario, lower temperature increases are projected and more severe decreases in rainfall are expected especially for the First Wet Season.

Tide gauge data in Guyana for the period 1951 to 1979 indicated a mean relative sea level rise of 10.2 mm yr^{-1}. This is about 5 times the global average and suggests a mechanism other than sea level rise may be operating on Guyana's coast.

The global circulation models (GCMs) indicate average rises of 2 to 4 mm yr^{-1} in the first half of the twenty-first century and rises of 3 to 6 mm yr^{-1} in the latter half. Therefore, in Guyana, sea level is projected to rise by about 40 cm by the end of the twenty-first century. If meltwater contribution from land ice is considered, then the rise can be about 60 cm.

The predicted sea level rise coupled to extremes in rain events and storm surges and increased wave action can exacerbate an already critical situation where water accumulation off Guyana's coast has been resulting in breaching and overtopping of the sea defences.

Climate Change Impacts

The impact of climate change on **water supply** is not very clear. Decreasing rainfall and increasing evaporation can lead to lower water levels in the rivers. Extreme rainstorm events can allow for flood conditions especially during cold phase ENSO events. Sea level rise can result in salt-water intrusions further up in the rivers. Ground water can also be vulnerable to this effect. Demand for water is expected to increase with increasing temperatures and the relative value of water for alternative uses would likely change as priorities are determined on the basis of urgency of needs.

The **energy sector** will also be affected. Demands for interior space cooling and possibly decreased hydro-generating potential supply from some river basins can pose some problems. Shifts in the seasonality of river discharges and reduced rainfall will have to be considered in determining hydropower sites and periods of water storage.

In the **agriculture sector,** using analyses based only on changes in climate variables, yield losses will affect sugar and rice. These losses may be triggered by increased water demands from crop transpiration and greater respiration losses as a consequence of higher temperatures. There may be changes also in yield quality due to a decreased diurnal temperature range resulting in, for example, decreased sucrose content. There is uncertainty in assessing the effect of fertilizers and pesticides on crop yield due to the projected increase in temperature. It is possible that adjustment of levels of fertilization may be an effective stabilizing response in extreme years.

Spatial shifts may have to be considered as climate change takes effect. There may be the need for a substantial switch of crops or species of crops in particular areas. In addition, changes in farm profitability can be expected to affect non-agricultural sectors of the Guyanese economy.

Major studies will have to be done to examine the advantages of increased CO_2 concentration and the effects of increased temperature, rainfall and evaporation on the major crops in Guyana. Also, it must be noted that the sensitivity analysis done in this Communication merely identifies the vulnerable areas and should form the basis for further evaluation and planning.

A CO_2-induced climate change can impact on the **forestry sector** in a similar way to those for agriculture. However, there will be the need to consider the impact of increased CO_2 fertilization on forest growth. If the dry seasons get drier, then this may impose severe constraints on forest growth and may be critical in determining species response.

The Holdridge classification system was used together with the climate scenarios to determine the possibility of change in the sector. With a doubling CO_2 concentration, indications are that the forests in southern Guyana may be affected with the *shrub savannah* spreading southward to replace *tall evergreen forest*. With a tripling CO_2 concentration, the same areas can be affected. However, the northwest may also be affected by a change to *shrub savannah* types. Again, the sensitivity analysis must be guided by further studies.

The **Coastal Zone** is identified as being the most vulnerable part of Guyana because sea level rise will be expected to add to the direct climate impacts of temperature rise, rainfall decrease and evaporation increase. It is also the part of Guyana where adverse impacts will directly affect a large percentage of the Guyanese population.

Two **vulnerable zones** have been identified in the coastal zone. ***Impact zone I*** comprise the western Essequibo areas where the coast is not protected by man-made structures**.** ***Impact zone II*** is the densely populated regions comprising Berbice, Demerara and the eastern part of Essequibo that are protected by man-made structures. In both zones, drainage is a problem. The Government will have to develop a programme to address the issues of coastal stress taking into consideration the impacts of climate change and sea level rise. Decisions will have to be made, on the basis of detailed analyses, on areas that shall be protected or accommodated or perhaps abandoned in the face of accelerated sea level rise.

Since the coastal zone affects a large percentage of the population, it will be necessary to examine the implications of climate change for water resources (effects of salinity in estuaries and aquifers), agri-culture, fisheries, human settlements, human suffering and loss of lives, tourism and health. Many data gaps exist and institutional capacity to examine these issues is not adequate. These shall have to be addressed. The work started under the Caribbean Planning for Adaptation to Climate Change (CPACC) programme should be continued possibly as components of the next phase of CPACC.

1.5 ADAPTATION MEASURES

Adapting to the impacts of climate change will require substantial financial and technical assistance. The overall goals of adaptation are to promote sustainable development and to reduce vulnerability. Sustainable development will entail ensuring economic development of all administrative regions, protection of the environment and equitable distribution of the wealth of the nation. Reduction of vulnerability will require minimizing of the risks of the impacts, reducing economic losses and alleviating hardships while building the institutional response mechanisms for detecting and warning of the signals of the impacts and for responding to emergencies and other activities required to address vulnerable ecosystems.

The impacts of climate change are likely to exacerbate an already “stressed” situation. Already, coastal and estuarine defences are being eroded by the sea; the number of human settlements are increasing in vulnerable low lying areas; health services are overburdened; mining activities are changing the banks and bottom topography of rivers in the hinterland and droughts and floods affect parts of Guyana on an annual basis. It is therefore necessary that climate change measures be combined with measures already identified to deal with current problems. The goals and objectives of the National Development Strategy can be realised by considering climate change adaptation and abatement measures.

The response options will obviously depend on the level of vulnerability in the region, or part of a region which is affected. It is first necessary to ensure that the capacity to detect, plan and respond exists in all relevant sectors. It is therefore a priority that capacity building be addressed at all levels of government and in the sectors. Another necessity is for climate change adaptation options be incorporated into national and sectoral policies such as economic development policy, disaster prevention and management, and environmental management plans.

The governmental capacity to deal with climate related issues need strengthening. Local communities are sometimes not aware of their vulnerability to the effects of global warming. The uncertainties in the predictions and impacts often create a resistance towards policy development and capacity building to deal with future vulnerable situations. Currently, the response mechanism is a reactive one where the problem is dealt with when it starts.

Signals of climate change and its impacts in Guyana have to be observed and studied. The monitoring and research capabilities of the scientific agencies will need strengthening. A very important monitoring deficiency is in impact monitoring. There will be a need to effect a comprehensive monitoring programme which will provide the impact signals on erosion, inundation, changes in pest abundance, health problems, changes in fisheries, rice and sugar yields, etc.

Planning is essential for addressing adaptation options. The capacity to identify options must be in place as is the capacity to respond to the adverse impacts of climate change. Disaster-prevention agencies such as the Civil Defence Commission, the military, non-governmental organisations (NGO's) and local communities must be prepared to respond effectively to abrupt and prolonged adverse conditions. Communication with local communities is a necessity for timely adaptation responses.

The adaptation strategy must consider, on the basis of analyses of data, precautionary actions to prevent loss. A controlled programme of actions to protect, retreat and/or accommodate the rise in sea level and to respond to other impacts will be necessary. Several options and their costs/benefits can be considered for adoption, tolerating short term loss is one such option, which can be considered. Spreading or sharing losses, changing use or activity, changing locations and/or restoration of damaged systems are all options, which can be chosen depending on the area and the impact being considered.

It is recommended that response options be considered in terms of short term (2000-2005), medium term (2006-2020) and long term (2021 and beyond). Options are recommended for each sector. However, many of these options can also be said to be options for sustainable development and can therefore be addressed as national efforts within the framework of the National Development Strategy (NDS). However, the coastal zone will demand urgent necessary actions since it is here that the impacts will be most severe. Anticipatory actions will have to be a major part of the strategy to minimize the effects of rising temperatures and seas.

1.6 MITIGATION MEASURES

Guyana has an obligation, under the Convention, to implement measures to mitigate emissions of GHGs into the atmosphere. The major sectors are the Energy sector, the Agriculture sector and the Waste sector. Mitigation will involve technology transfer in order to make energy use more efficient, to change farm practices and to reduce emissions from waste management. The strategies that have been recommended are considered for short term (2000-2005), the medium term (2006-2020) and the long term (2021 and beyond).

In the Energy sector, modernization of the current electricity power generating plant is a necessary first measure to be considered. Leakages in the distribution system must also be considered. The use of renewable sources of power such as hydropower, solar and wind should be addressed in the short, medium and long terms. Policy issues in this sector have been examined and it is recommended that the Energy Sector Reform Act should be extended to include climate change mitigation issues

1.7 TECHNOLOGY TRANSFER

The relevant technologies are of two types: mitigation technologies and adaptation technologies. Mitigation technologies address the reduction of emissions of GHGs while adaptation technologies address the reduction or elimination of the consequences of the climate change impacts.

Mitigation technologies include fuel efficiency, renewable energy sources, climate-friendly agricultural and forestry practices. These are all technologies, which can be transferred to Guyana via the private sector and through business partnerships or linkages. However, the adaptation technologies, particularly the coastal adaptation technologies will mostly be transferred to government since the private sector may not consider sea defence, drainage and irrigation, etc. as activities for which investments will bear attractive financial results in the short term.

The government will have to review policy directives that are likely to impede technology transfer; it will also have to support capacity strengthening to accelerate such transfers. These areas include inadequate human and institutional capabilities and inability to access, select, import, develop and adapt appropriate technologies. The capacity of the Institute of Applied Science and Technology (IAST), National Agricultural Research Institute (NARI), etc. to play a major coordinating role in technology transfer will have to be strengthened.

1.8 MONITORING AND UNDERSTANDING CLIMATE CHANGE AND IMPACTS: Systematic Observation and Research; Education, Public Awareness and Training.

Anthropogenic Climate Change and its impacts can affect all sectors of socio-economic development in Guyana. It is therefore essential that the people of Guyana be fully prepared to respond to the adverse impacts. This will require actions to be undertaken to observe the effects of global warming and to conduct studies into the possible future impacts and response mechanisms. The education system must be involved in acquainting students with the effects of global warming and the issues that are being addressed at the national and international levels. An aggressive public awareness programme and training from the university levels down to the primary school level and at the community level will be necessary to facilitate Guyanese with the skills to respond to the impacts of climate change

To detect climate change, long periods (over 100 years) of reliable and more sensitive climate data have to be available for a network of locations, which can indicate the regional variations in the climate. A relatively long period of impact monitoring is also required if accurate deductions, on the impacts, are to be made. Information must be generated from available data to provide inputs for the climate models. These models will output future projections on the details and choices of the responses that can be adapted to mitigate climate change.

The mandate for monitoring the climate system lies with the Hydrometeorological Service of the Ministry of Agriculture. However, many vacancies exist at the professional level; other constraints include inadequate training, lack of equipment, inability to attract field and office technicians, effecting proper maintenance, etc.. All these setbacks contribute towards an insufficient capacity in Guyana, to monitor climate and climate change.

The impacts of severe climate variability will affect socio-economic development. Responses may not be appreciated or understood by those who shall be affected at this time. Hence, education, public awareness and training will be essential tools to increase understanding and appreciation.

The Environmental Protection Agency (EPA) is promoting environmental education and public awareness in Guyana, especially by the already drafted National Environmental Education and Public Awareness Strategy (NEEPAS, 1999). However, Climate issues have not been directly addressed by the NEEPAS while related issues were addressed. As such, the EPA should include climate education as one of the major issues to be addressed by NEEPAS so as to avoid duplication of efforts.

1.9 MAJOR RECOMMENDATIONS

Guyana, based on the 1994 national inventory, makes only a minor contribution to emissions of greenhouse gases. However, increases in the global mean temperatures could have significant impact, especially on the coastal plain and on activities including the dominant agriculture sector. Policies and programmes to address climate change, and to further reduce emissions, need to be developed and implemented. The preparation of Guyana's Initial National Communication showed that Guyana is not quite prepared, due to inadequate human, institutional and financial resources, to address its commitments under the UNFCCC.

The recommendations below are pivotal for sustainable development and for response to the related climate change issues. They should be combined with the measures outlined for implementing the National Development Strategy.

Establish a Climate Change Unit in a government agency. This Unit should be responsible for delivery of Guyana's GHG programmes and will provide a central point of contact for industry and other stakeholders. The Unit will reflect the priority that the government is giving to domestic actions to reduce GHG emissions.

Government should garner financial resources and support, to protect agriculture and other infrastructure on the coast as a consequence of impacts and vulnerabilities predicted for this region. Therefore, planners should consider these likely impacts when considering further coastal development and encourage settlements in suitable interior locations.

Update the inventory of coastal assets and quantify in terms of monetary values, and identify areas of great threat to the sea and future sea-level rise. Upon completion of this survey, carry out sea defence work on areas that are most vulnerable to the sea and have substantial values in terms of assets for possible protection while discouraging major development in coastal areas that already have little or no value in assets and no sea defence.

Carry out research in the the agriculture sector to develop or acquire special plant species that will adapt to the predicted climate change, or to acquire the most appropropriate technologies that will foster adaptation in all sectors of Guyana's economy, most importantly the agriculture, forestry, energy, water resouces and buildings sectors.

Boost the use of renewable energy: The Government should continue to work with local Regional Authorities, private sector and communities to set a mandatory target to source a percentage of electricity from renewable sources. Solar and wind energy projects along with hydropower can drive the urban electrification programme by identifying whole villages for renewable energy applications.

Calculate baseline emissions and local emission factors: Due to lack of adequate activity data, the national inventory was calculated using estimations and application of indirect default emission factors. Guyana needs to develop the capacity to prepare emission factors for local conditions and not relying on indirect default factors. This should apply to all sectors and all greenhouse gases.

Accelerate energy market reform: Efficiency standards for fossil fuel electricity generation should be drawn-up and be put into Law to ensure that Guyana adopts the best practices. The reform will also deliver economic as well as environmental benefits to the nation.

Improve fuel efficiency in land, sea and air transport: Mandatory fuel efficiency measures, including acquisition of high grade fuel and highly efficient engines must be purchased, developed and implemented.

Implement national efficiency codes and standards for buildings, all appliances (locally produced and imported) and a wide range of industrial equipment so that energy efficiency can be taken into the offices, the homes, the factories and the commercial houses.

Foster local carbon sequestration programmes, including revegetation and soil carbon storage programmes to increase sinks for GHGs. The Government can facilitate partnerships between the forestry, corporate sector and local communities through the funding of revegetation projects. Local Government can also be involved in projects to promote planting of trees, etc. in the communities.

Develop a programme for climate protection to be implemented in the municipalities and in the regions by fostering emissions reduction via energy efficiency, "clean" transportation , management of waste, climate consciousness and adaptation activities.

Develop programmes to foster education, public awareness and training in the field of climate change related issues.

Extend the National Land Use Plan to accommodate further development and thrust into new areas for agricultural expansion and potential settlements in the hinterland.

Accelerate the development of a policy on the implementation of Geographical Information System and training to strengthen the capacity, within the natural resources sector to provide reliable, timely and technical information to the government.

Develop emergency programmes for civil defence and rescue to adequately respond to emergencies that may arise from sea level rise, floods and droughts.

2.0 INTRODUCTION

CHAPTER TWO

INTRODUCTION

(BACKGROUND INFORMATION)

This Section of the National Communication provides information on Guyana's obligations under the Convention and on the National Circumstances that prevailed during 1994, the base year for Guyana. It also provides information on the geography, geology, climate, history, demography, economy, energy sources, land use, forestry and biodiversity.

Our National Bird – The Canjie Pheasant

2.0 INTRODUCTION

2.1 General

Guyana signed the United Nations Framework Convention on Climate Change (UNFCCC) at the United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in June 1992.

The ultimate objective of the UNFCCC is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system and within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner (Article 2).

The Convention entered into force worldwide on March 21,1994 (90 days after the date of deposit of the fiftieth instrument of ratification). Guyana ratified the Convention on August 29, 1994 subsequently entering into force on November 17, 1994.

2.2 Guyana's Obligations

The commitments under the UNFCCC pertain to all the greenhouse gases not controlled by the Montreal Protocol on Substances that Deplete the Ozone Layer. Guyana, being a developing Country Party not included in Annex 1 nor Annex 2 will prepare its communications under the guidance of the following Conference of the Parties (COP) decisions:

- Decision 10/CP.2, including the annex guidelines for the preparation of initial communications from Parties not included in Annex 1 (DOC FCCC/CP/1996/ 15/Add.1)
- Decision 11/CP.2: Guidance to the Global Environment Facility (FCCC/CP/1996/15/Add.1)
- Decision 2/CP.4: Additional guidance to the operating entity of the financial mechanism (FCCC/CP/1998/16/Add.1)
- Decision 12/CP.4: Initial national communications from Parties not included in Annex 1 to the Convention (FCCC/CP/1998/16/Add.1)
- Decision 11/CP.1: Initial guidance on policies, programme priorities and eligibility criteria to the operating entity or entities of the financial mechanism (FCCC/CP/1995/7/Add.1)

2.3 Convention Guidance

Articles 4.1 and 12.1 require Guyana to communicate to the COP:

(a) A national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the COP;

(b) A general description of steps taken or envisaged by Guyana to implement the Convention; and

(c) Any other information that Guyana considers relevant to the achievement of the objectives of the Convention and suitable for inclusion in its communication, including, if feasible, material relevant for calculations of global emissions trends. Article 12.4 permits Guyana, on a voluntary basis, to propose projects for financing, including specific technologies, materials, equipment, techniques or practices that would be needed to implement such projects, along with, if possible, an estimate of all incremental costs, of the reduction of emissions and increments of removals of GHG, as well as an estimate of consequent benefits.

Articles 4.3 and 12.5 oblige Guyana to make its initial communications within three years of the availability of financial resources to meet the agreed full costs of the preparation of the national communications.

2.4 COP Decision Guidance

- **COP 1** requested the Global Environment Facility (GEF) to give priority to funding agreed full costs (or agreed full incremental costs, as appropriate) incurred by developing country Parties in complying with their obligations.

- **COP 2** decided to adopt guidance to the GEF, as the interim operating entity of the financial mechanism of the Convention and also decided on guidelines, facilitation and process for consideration in communications from non-Annex 1 Parties.

- **COP 4 decided** on additional guidance to the GEF for funding implementation of adaptation response measures (Article 4.1), building of capacity for participation in systematic observational networks to reduce scientific uncertainties and assisting in developing, strengthening and/or improving national activities for public awareness and education on climate change and response measures, among other decisions. COP 4 also decided that, among other things, communications from non-Annex 1 Parties shall be considered in a facilitative, non-confrontational, open and transparent manner.

2.5 The Enabling Activity Project

A Project Document "GUY/97/G31/A/IG/99" titled "Enabling Guyana to Prepare its Initial National Communications in Response to its Commitments to the UNFCCC" was signed on June 5, 1998 between the Government of Guyana and the United Nations Development Programme (UNDP) whereby the UNDP/GEF provided a maximum of US$196,730 in order to enable Guyana to prepare its Initial National Communication to the Conference of the Parties to the UNFCCC. The Project had the following components:

- An inventory of greenhouse gases following the guidelines decided by the Conference of Parties (COP);

- An assessment of potential impacts of climate change in Guyana;

- An analysis of potential measures to abate the increase in GHG emissions and to adapt to climate change;

- Preparation of a National Action Plan to address climate change and its adverse impacts; and

- Preparation of the Initial National Communication of Guyana to the COP.

The following actions were taken in order to respond to the objectives of the Project and to implement the project successfully:

- A Project Steering Committee, titled "National Climate Committee (NCC)" was established. It is chaired by the Chief Hydrometeorological Officer, who is the Climate Change focal point.

- A Project Coordinator was appointed to work full-time on the project.

- An international consultant on Climate Change and other experts were appointed to advise the Project Coordinator and to guide the national agencies on methodologies, data gathering and analyses.

- A National Task Force was set up to prepare the National Action Plan and the Initial National Communication.

- An Internet web site was set up to provide information on climate change activities in Guyana.

2.5.1 The National Climate Committee (NCC):

The NCC is comprised of participants from the following agencies:

- Environmental Protection Agency
- Hydrometeorological Service
- Institute of Applied Science and Technology
- Guyana Forestry Commission
- Guyana Manufacturers Association
- Private Sector Commission
- Guyana Energy Agency
- Guyana Natural Resources Agency
- Ministry of Trade, Tourism and Industry
- Ministry of Finance
- Ministry of Housing & Water
- Ministry of Health & Labour
- Ministry of Agriculture
- Ministry of Foreign Affairs
- University of Guyana
- Office of the President
- Guyana National Bureau of Standards

The Terms of Reference of the NCC are:

- Advise the relevant Ministers on developments and the need for policies and regulations in areas of climate change activities.

- Make recommendations to the Adviser to the President on Science, Technology, Energy and Environment on national measures to address issues related to several climate-related conventions and associated protocols.

- Promote technical, scientific, technological and financial co-operation among Institutions/ Organizations with responsibility for climate change activities.

- Monitor and evaluate the implementation of action programmes related to the national obligations under the climate-related conventions and associated protocols.

- Oversee the country's activities for the Inter-governmental Panel on Climate Change (WMO-UNEP).

2.5.2 The National Task Force:

The team was tasked with the job of developing the National Action Plan and the Initial National Communication. It included the following persons:

1. Ms. Sandra Bevan - Guyana Energy Agency
2. Ms. Verly Cordis - Ministry of Agriculture

3. Ms. Ravita Diaram - Environmental Protection Agency
4. Mr. Zainool Rahaman - Hydrometeorological Service
5. Ms. Deborah Montouth - Ministry of Housing and Water
6. Ms. Susy Lewis - Guyana Natural Resources Agency
7. Mr. Anthony Ross - Guyana National Bureau of Standards
8. Ms. Maria Kattow - Guyana Forestry Commission
9. Ms. Denise Simmons - University of Guyana, Environmental Studies Unit

The team's work was coordinated by the Project Coordinator of the Enabling Activity Project.

2.5.3 Workshops

The following workshops were held to facilitate the preparation of the Initial National Communication:

- **The Initiation Workshop** was held on October 19, 1999 to provide information on climate change issues, identify the sector agencies (and sector coordinators) and to discuss methodologies and other issues.

- **The Inventory of Greenhouse Gases Workshop** was held on October 19 – 21, 1999 and provided training to sector agencies in developing the sectoral inventories.

- **The Vulnerability and Adaptation Workshop** was held on October 21, 1999 and provided training to sector agencies in the operation of a suitable methodology of vulnerability assessment, adaptation issues, data collection and data gap studies.

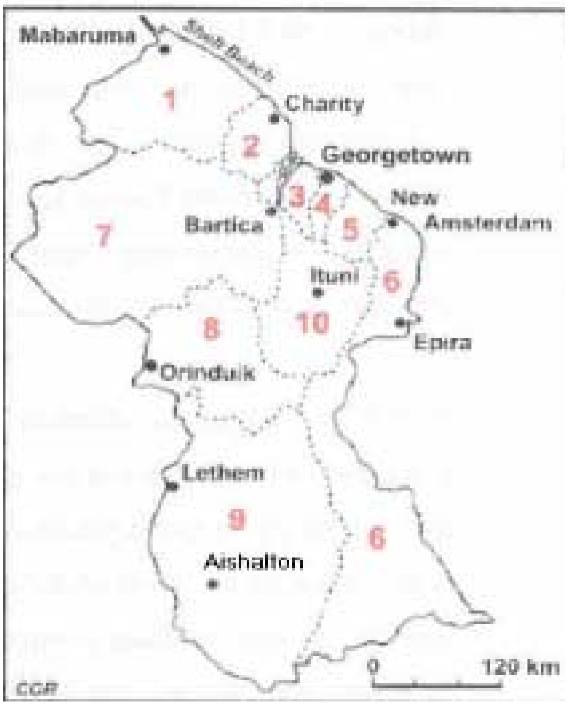
- **The Workshop on Mitigation Analysis** was held on October 22, 1999 and provided training in GHG abatement analysis and mitigation methodologies and programmes.

- **There were other working group** meetings of the task force to clarify problem issues and data gap analyses. These were held on March 01 – 03, 2000.

- **The Task Force provided a draft of the Communication for the National Strategy Workshop**, which was held on June 23, 2000 and the National Action Plan for responsive measures along with the other components of the Initial Communication were discussed and fine-tuned for submission to Government.

CHAPTER THREE

NATIONAL CIRCUMSTANCES 1994



Administrative Regions

3.0 NATIONAL CIRCUMSTANCES 1994

3.1 GEOGRAPHY

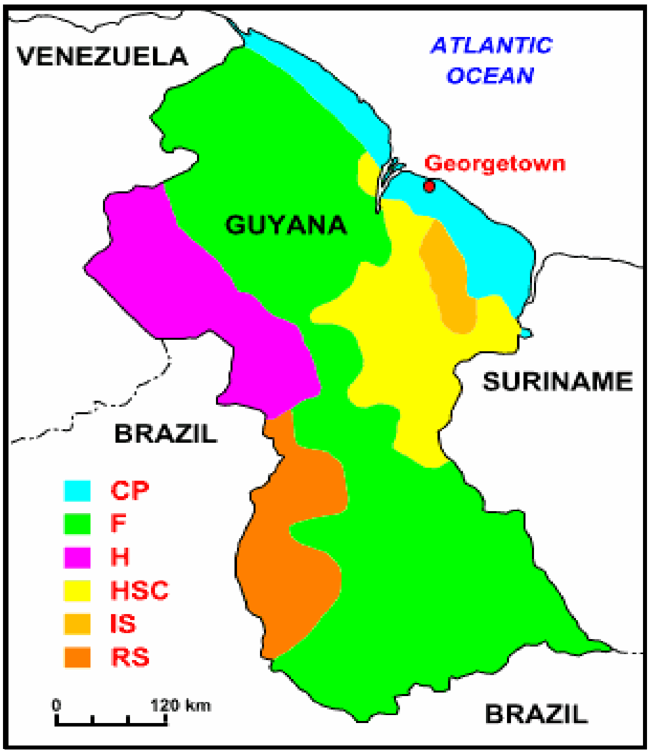
3.1.1 General

Guyana is a tropical country, situated on the northeastern coast of the continent of South America between 1 degree and 9 degrees north latitudes, and 56 degrees and 62 degrees west longitudes. It is bounded on the north by the Atlantic Ocean, on the east by Suriname, on the south and southwest by Brazil and on the west by Venezuela. It occupies a total landmass of approximately 216,000 km^2 and has a coastline that is about 434 km long and a continental extent of about 724 km. About 35 percent of the country - the area approximately below 4 degrees north latitude – lies within the Amazon Basin. There are three main rivers – the Essequibo, Demerara and Berbice - which all drain into the Atlantic Ocean. Noteworthy, is that the three counties – Essequibo, Demerara and Berbice derive their names from them.

Guyana has close relations with the Caribbean countries because of its similarities due to its past British Colonial influence and is a member of the Caribbean Community (CARICOM), which is headquartered in Georgetown, the Capital City.

Guyana has five (5) natural geographic regions:

- The Coastal Plain (CP)
- The Hilly Sand and Clay Region (HSC)
- The Highland Region (H)
- The Forested Region (F)
- The Savannah Regions (IS & RS)



Geographical Regions

3.1.1.1 The Coastal Plain (CP):

The Coastal Plain lies on the northern edge of the country. The width of this region varies from 77 km in the east to a mere 26 km in the western Essequibo region. Topographically this region is virtually flat and, comprising heavy (Holocene - Pliocene age) fluvio-marine clays, is prone to flooding during the rainy season. A series of sand ridges (0.5m to 2.5m high and between 10m to 600m wide) running almost parallel to the existing coastline are the main relief variation, often impeding drainage to create pegasse swamps and, in the case of western Essequibo coast, lakes. Sand ridges (or possible geologic fault) may also be responsible for the orientation of the many rivers which dissect the coast. A cyclical process of erosion and accretion, related to the Equatorial and Guiana currents off-shore and to local longshore drift, has led to the build-up of submarine bars across the mouths of the rivers requiring periodical dredging to clear siltation.

A complex system of drainage and irrigation canals allow the fertile clays to be utilised for sugarcane and rice cultivation; cattle ranching; and coconut, vegetable and fruit production which all add to the hub of economic activities supporting the 90 percent of the total population that inhabit this region. The main urban centres are found within the Coastal Plain and most commercial activities are concentrated there.

3.1.1.2 The Hilly Sand and Clay Region (HSC):

Occupying the northeastern section of Guyana, this undulating upland varies in height from 2 m to 400 m. This geosynclinal trough of sediment is thickest (2000m) in the Berbice Region, increasing towards the Corentyne River and continues into Suriname. Of Pliocene-Pleistocene age, the unconsolidated material comprises 85 percent white quartz sand with pockets of brown and yellow sand. The high porosity enhances infiltration and leaching of the thin layer of dark humus of the topsoil, giving stream water a reddish tint.

Despite low drainage density relative to other regions, four relatively small rivers originate in the HSC: Abary, Mahaicony, Mahaica and Canje. In some areas, the crystalline basement rock outcrops to create hills, as well as falls and rapids across rivers.

Dry evergreen climax vegetation includes species such as dakama (*Dimorphandra conjugata*) and wallaba (*Epeura falcata*), widely used in Guyana and the Caribbean as electricity and fencing poles. A Savannah belt, 95 km from the coast towards Orealla, is mainly used for cattle ranching and citrus. Economically, the HSC is home to bauxite deposits that have been mined for most of this century. Major mining centers: Linden, Kwakwani and Ituni have high population density in comparison with agricultural settlements.

3.1.1.3 The Highland Region (H)

The Pakaraima Mountains form a part of the extensive Guiana Highlands that covers an area of 1,300,000 km^2 in Guyana, Venezuela and Brazil. It comprises a series of horizontal beds of quartzitic sandstone, conglomerate and intrusive rocks of almost Pre-Cambrian age. Varying in height from 500 m to 2777 m at Mt. Roraima, this formation comprises a series of plateaux and tablelands with sharp edges and precipitous escarpments. The plateaux are dissected by many streams and gullies thereby creating deep gorges and waterfalls.

Large tributaries of the Essequibo rise in this upland namely the Cuyuni, Mazaruni and Potaro Rivers which have gold and diamond deposits. The Potaro is well known for the world-famous Kaieteur Falls, which at 225 m is the highest sheer-drop waterfall in the world.

There are small settlements in this region of thin soil and low-grade montane vegetation. Communities are small and may be temporary mining sites or indigenous in nature. Government centres provide basic services such as health and education.

3.1.1.4 The Forested Region (F)

This large physiographic region almost spans the entire length of the country with elevation increasing southwards from 90 m to about 210 m culminating in the Akarai Mountains. Its geomorphology is closely associated with differential weathering of rocks, vulcanicity and structural patterns. Geologically the region forms part of the Pre-Cambrian Brazilian Shield with varied rock types including granite, gneiss, amphibolite, shale and quartzite. Latosols and numerous laterite-capped hills and ridges, typical of equatorial areas, are common. This is also the tropical rainforest region of Guyana, a continuation of the Amazon Forest. Among the vast untapped forest resources, wood species include the highly commercially valuable greenheart (*Chlorocardium rodiaei*), crabwood (*Carapa guianensis*) and purpleheart (*Peltogyne venosa*). Selective logging is done in a sustainable manner in the forest. This region is also rich in minerals and gold deposits. Mining of gold also occurs in this region.

3.1.1.5 The Rupununi Savannah (RS) and Intermediate Savannah (IS)

The Savannahs consist of the Intermediate Savannah and the hinterland or Rupununi Savannah. The Intermediate Savannah (IS), in the eastern part of the country, lies between the Coastal Plain and the Hilly Sand and Clay region. The larger interior or Rupununi Savannah (RS) is located in the southwest and is divided into the North and South Savannahs by the Kanuku mountains. The North Savannah is more hilly than the South Savannah and grasslands characterize both areas. Cattle ranching and farming are two of the main activities in the Interior Savannah.

3.1.2 The Geology of Guyana

The geology of Guyana gives insight into the lack of present day tectonic activity in Guyana and indicates that Guyana is not affected whatsoever from the Caribbean, North, Central and South American plates, and the Atlantic and Pacific Oceanic plates.

British Guiana is a country of humid tropical climate situated on the northern coast of South America and forms part of the ancient Guyana Shield (Bleakley 1964). It lies between 2-9° N Latitude and 56-62° W Longitude. The Guiana Shield is composed of Pre-Cambrian gneises, schists, meta-sediments, and meta-volcanics and associated granites.

The Pakaraima Mountains, in the hinterland region was formed by early volcanic activity, is composed of a tabular sandstone formation and intruded by thick sills of dolerite. Sills and dykes of dolerite are also found throughout the Pre-Cambrian basement rocks while a fringe of tertiary and recent sediments extend along the Atlantic Coast.

3.1.2.1 Plate Tectonics

The theory of Plate Tectonics is principally a description of the geometry and kinematics by which the earth's lithosphere experiences displacements.

3.1.2.2 Evidence of Present Tectonic Activity

The present tectonic activity of the Caribbean region is evidenced by large variations in topographic elevations from deep sea trenches to high mountains, by linear chains of volcanoes, by a high degree of seismicity, by large negative and positive free-air gravity anomalies, and by high heat flow in some localised areas" (Bowin 1976).

The active zones of the Caribbean region indicate that there are at least three zones of underthrusting at present. . Chase and Bunce, 1969, Bunce and others, 1970, Bowin, 1973 have all documented this zone of underthrusting.

If the Caribbean and South American Plates converge at a rate of 2 cm/yr, the South and North American plates might converge along the northwest to the Gulf of Mexico area at a rate of about 0.35 cm/yr without affecting the Guiana shield and the coastline in particular.

3.1.2.3 Coastal Subsidence

There is a hypothesis that the coastal area of Guyana may be subsiding. This hypothesis is based on the fact that ground water on the coast is being withdrawn at a faster rate than the aquifer can be recharged, resulting in a loss of head in some areas (over 14 m in Georgetown) due to the high density of wells. Hence the resulting postulate. Therefore, sea level rise would be accentuated as a result of subsidence occurring on the coastal area. There has been no scientific study into the recharge of coastal aquifers and the hypothesis needs to be investigated.

3.2 CLIMATE

3.2.1 General

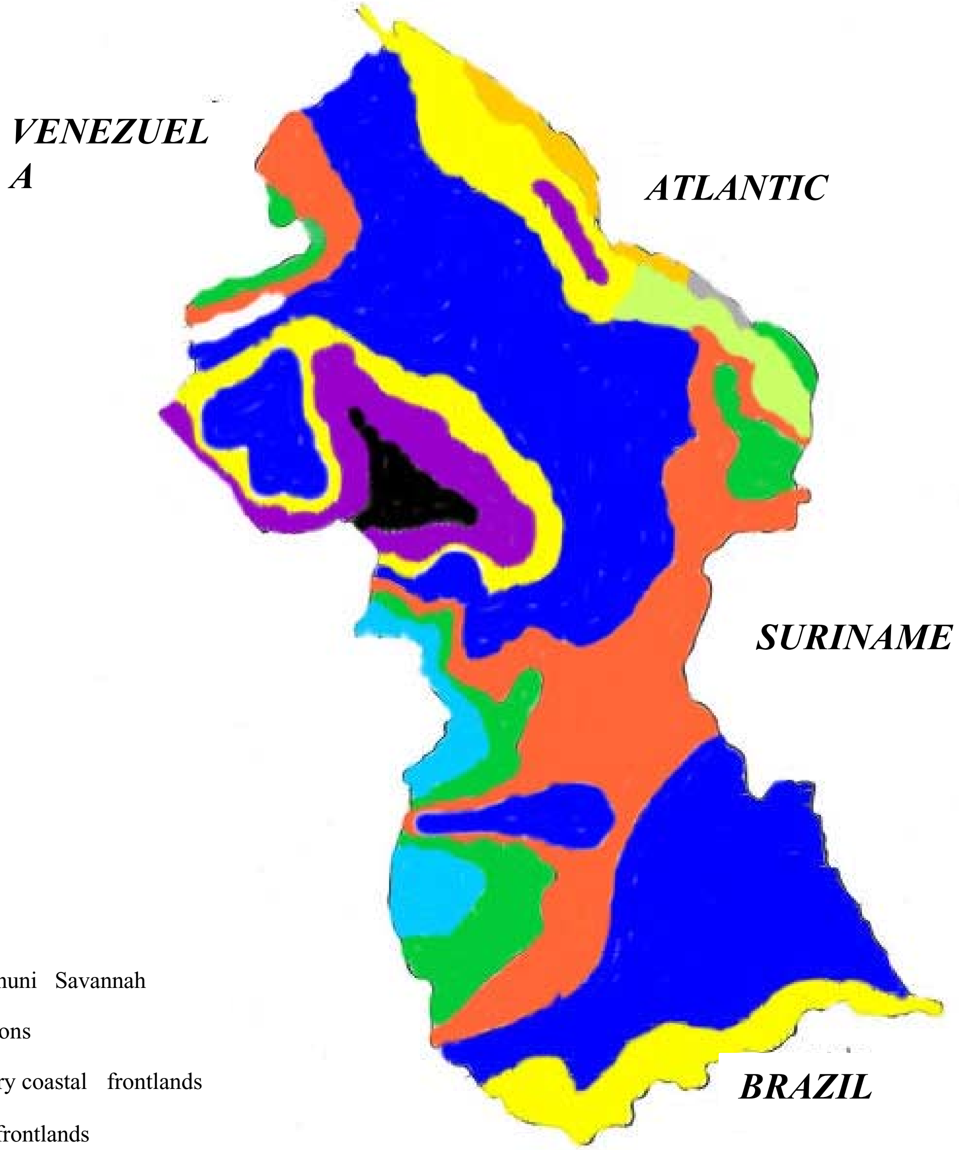
Guyana lies within the equatorial trough zone and the climate is influenced primarily by the seasonal shifts of the Inter-Tropical Convergence Zone (ITCZ). The seasons and climate are determined mainly by the variation in rainfall patterns. This is so because the spatial and temporal variations of other meteorological parameters are relatively small.

3.2.2 Different Seasons of the Year

Seasons in Guyana are identified by rainfall amounts resulting from the north/south movement of the Inter-Tropical Convergence Zone (ITCZ). There are two wet and two dry seasons in a calendar year:

SEASON	PERIOD
1. First dry season (FDS)	Late January to early April
2. First wet season (FWS)	Late April to early July
3. Second dry season (SDS)	Late July to early November
4. Second wet season (SWS)	Late November to early January

The duration of the seasons can be contracted or extended depending on the regional climate systems which are prevailing at the time. The intensity of rainfall in a season can decrease or increase as a consequence of the intensity of the ITCZ or other weather system influencing Guyana at the time.



Map of Rainfall – climatic regions of Guyana

3.2.3 Rainfall

On the macro-scale Guyana can be described as having a Wet Tropical Climate. However, due to geographical influences such as mountains, ocean, etc. there is spatial variability of rainfall resulting in three major climate types on the meso-scale. These, based on our local classification are as follows:

- **Very Dry –** Areas with annual rainfall less than or equal to 1788 mm. Such areas are the Rupununi Savannah, the Intermediate Savannah, the Upper Cuyuni and the East Berbice Coast. The Secondary Wet Season is absent in the Rupununi Savannah and often absent in the Intermediate Savannah.

- **Wet-Dry –** These are areas with rainfall between 1778 mm and 2800 mm. This climate type is the most widely experienced one in the country and can be further subdivided into *Moderately Dry, Moderately Wet and Wet.*

- **Very Wet –** areas with annual rainfall above 2800 mm. This climate type can be subdivided into *Exclusively Wet, Exceedingly Wet and Extremely Wet.*

3.2.4 Duration of Sunshine

As a result of Guyana's proximity to the equator there is little variation in the hours of daylight. It varies from a minimum of 11.6 hours per day in December to a maximum of 12.5 hours per day in June. Bright sunshine is inversely proportional to rainfall. It therefore varies from an annual average of 4.5 hours per day in the Pakaraima Mountains to 7.0 hours per day on the coast. During the Wet Seasons, it can average as low as 3.0 hours and 6.0 hours per day respectively at these locations.

3.2.5 Temperature, Relative Humidity and Wind

Diurnal variation of temperature is smallest on the coast where the maritime effect is most pronounced. In that area daily maximum temperatures average 29.6 ^{o}C while daily minimum temperatures average 24.0 ^{o}C. However, the lowest temperatures occur in the mountainous regions. At Kamarang, daily maximum average 28.6 ^{o}C and daily minimum 19.6 ^{o}C. At the peak of Mount Roraima daily minimum temperatures are expected to average about 5.0 ^{o}C.

Seasonally, temperatures are higher in the dry periods with the highest temperatures occurring in September/October and the lowest in January/February. The October average daily maximum temperature ranges from 34 ^{o}C in the Savannahs to 30 ^{o}C at Kamarang and less in the higher regions. The January average daily maximum temperature ranges from 32 ^{o}C in the Savannahs to 27 ^{o}C at Kamarang while the daily minimum ranges from 23 ^{o}C in Georgetown to 19 ^{o}C at Kamarang. Relative humidity is high averaging about 70 percent in the Savannahs, 80 percent on the coast and 88 percent in the rainforest. Morning fog can be widespread and persistent in the hinterland districts.

Guyana’s coast is subject to the northeasterly trade winds with speeds of about 6 meters per second decreasing further inland where light winds generally prevail. However, in the Rupununi Savannahs the wind speeds approach that on the coast.

3.3 CLIMATE AND WEATHER SYSTEMS

There are many tropical and extra-tropical weather systems which influence Guyana's weather. The major ones are:

- **Inter Tropical Convergence Zone (ITCZ):** This convergence area is brought about by the confluence of the Northeast and Southeast Trade Winds. When the convergence is strong, copious rainfall is experienced but when it is weak rainfall may even be absent.

- **Tropical Waves:** During the hurricane season, these precursors of the hurricane can affect Guyana's coastal and inland areas particularly west of the Demerara River. It is the system which is responsible for larger rainfall amounts in the northwestern parts of the coast and is often the cause of the extension of the First Wet Season into the Second Dry Season.

- **Upper Level Troughs:** Especially during the Northern Hemisphere winter season, extra-tropical troughs in the upper Westerlies can push southward and create divergence zones which produce moderate to heavy rainfall especially when they interact with the ITCZ.

- **Southern Hemisphere Upper Troughs:** During the Southern Hemisphere winter, these troughs in the Westerlies produce cloud blow-ups in Amazonia and copious rainfall in Guyana's rain forest, inland areas and coast.

- **ENSO Events:** These are equatorial Pacific climate events that have dramatic effects on Guyana's seasons. When the Pacific is in the El Niño mode, as in 1997 - 1998, drought conditions can affect Guyana. When it is in the La Niña mode, as in 1996, flood conditions can affect Guyana. ENSO (El Niño/Southern Oscillation) events significantly change the intensity and duration of the traditional seasons and, in recent years the El Niño/La Niña modes have been alternating much more frequently.

3.4 HISTORY AND DEMOGRAPHY

3.4.1 History

"Guiana" was the name given to the land sighted by Columbus in 1498, and comprised modern Guyana, Suriname, French Guiana and parts of Brazil and Venezuela. It was not until a century later that the first Europeans settled in this area. Sir Walter Raleigh visited in 1595, after which several unsuccessful attempts to establish permanent settlements followed. The Dutch finally succeeded in the late 16th century with a settlement at Kyk-over-all on an island in the Essequibo River, when the Amerindians welcomed them as trading partners. Subsequently, colonies were set up in Berbice and Demerara too.

The establishment of these colonies led to the exploitation of the Amerindians and subsequently the African slaves that followed. During the 18th and 19th centuries, the three colonies changed hands several times. The British seized them from the Dutch but then lost them to the French who restored the colonies to the Dutch in 1783. The Dutch control ended when the British became the rulers in 1796. In 1815, the colonies of Essequibo, Berbice and Demerara were officially ceded to Great Britain at the Congress of Vienna and, in 1831, were consolidated as British Guiana.

Following the abolition of slavery in 1834, indentured labourers were brought to Guyana to work on the sugar plantations. They came primarily from India but also from Portugal, China and the Caribbean, this practice was discontinued by the British in 1917.

Many of the freed slaves settled in coastal villages and late moved to the towns as they developed. They became the majority of the urban population. The indentured labourers remained predominantly rural. The Amerindian population continued to live in the communal settlements in the hinterland.

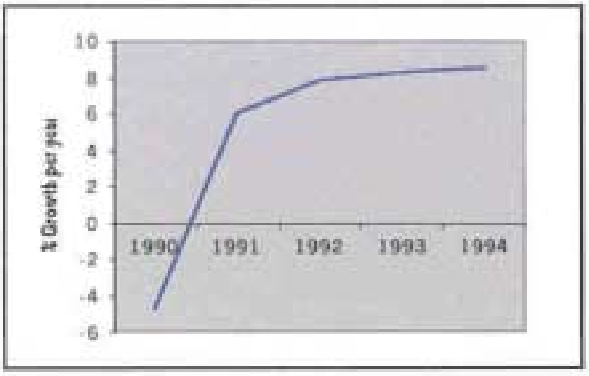
Guyana attained independence from Britain on May 26, 1966, and became a Republic within the Commonwealth four years later on February 23, 1970.

3.4.2 Demography

Guyana's population is approximately 750,000 and comprises six main ethnic groups:- East Indian, Africans, Amerindians, Chinese, Portuguese and Europeans. There are also a significant percentage of peoples of mixed race. East Indians and Africans comprise the majority of the population and originated from India and

Africa respectively. Compared to its present land area (214,970 km^2) the population of Guyana is relatively small – a population density which is less than four persons per km^2 of land area.

At the end of 1994, the population was estimated at 763,687 of which 376,269 were males and 387,418 females. Urban population represents about 33 percent of the total population. Life expectancy at birth for the year 1995 was 64 years, with males reaching 60 years and female 67 years. The death rate continues to decrease due to improved health care facilities and public awareness of health issues. It was 7.1 per thousand in 1994.



GDP growth rate

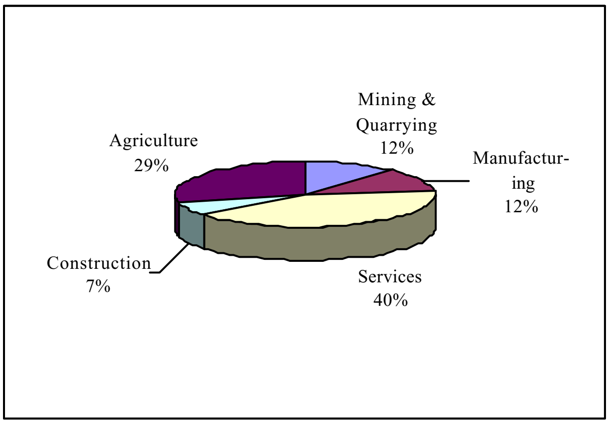
3.5 THE ECONOMY

With a Gross Domestic Product (GDP) per capita of US $528 in 1990, Guyana was the second poorest country in the Western Hemisphere, after Haiti. Guyana's economy was responsive to structural adjustment measures, with real GDP growing by 8.5 percent in 1994. Since 1991, this positive growth rate reflected the effects of price liberalization, a market-determined exchange rate and the positive results of private sector investment in the gold, timber and rice industries. The consumer price level rose by 16.1 percent during 1994 after rising by 7.7 percent in 1993. The overall deficit of balance of payments rose to US M$63.9 in 1994 from US M$49.7 in 1993.

Guyana remained committed to a market-determined exchange rate. During the year 1994, the exchange rate depreciated by 9 percent to reach G$142.50 per US dollar in December 1994. All five sectors of Guyana's economy have special relevance to climate change issues. These are the agriculture, forestry and fishing sectors which made up 29.2 percent of the GDP in 1994, the manufacturing sector 12 percent, the services sector 39.6 percent, the mining and quarrying sector 12 percent and the construction sector 7 percent.

3.5.1 Agriculture, Forestry and Fishing Sector

The agriculture sector is the single most important sector of Guyana's economy, both in terms of foreign exchange generation and the number of persons employed. In 1994, this sector increased by 12 percent, compared with 6 percent recorded during 1993. This improvement reflected the recovery of sugar output and the expansion of rice, timber and other crop production.



Sector Contribution to GDP

The sugar industry is expected to continue to be one of the important engines of growth in the future especially since it gained access to non-traditional regional markets in addition to traditional markets. Output of sugar for 1994 was 256,669 tonnes, 4 percent above the 246,528 tonnes recorded for 1993. This additional production reflected the impact of a stable political climate and good weather conditions experienced in the year.

Despite the constraints in irrigation, drainage and the poor state of access roads, rice output for 1994 was 233,435 tonnes, which was 11 percent higher than in 1993. The liberalization of the rice market, and the continuous rise in the price of paddy resulting from a strong external demand for rice affected the strong supply response in the year.

After declining for several years, livestock output recorded a positive growth for 1994. The growth for this sector rose by 15 percent compared with 11 percent for 1993. The principal contributors to this performance were poultry and eggs, increasing by 53 to 112 percent respectively.

The output of the forestry sector continued to be influenced by the new governmental policies, which facilitated significant foreign investment. These investments, the ability to pay higher wages, training and the exploitation of new markets induced higher production. Output of timber increased to 469,557 cubic meters or 98 percent over that of 1993.

Value added in the fishing industry increased by 7 percent during 1994. Gross output of fish, small shrimp and prawns increased in 1994.

3.5.2 Manufacturing and Service Sector

Growth in output in the manufacturing sector during 1994 was 6 percent compared with 3 percent during 1993. This resulted primarily from the 11 percent expansion of rice sector. There were also encouraging trends in other manufacturing activities, primarily consumer non-durables and sugar processing, which grew by 6 and 4 percent respectively during 1994. The growth in non-durables was explained by significant increases in pharmaceuticals, garments, soft drinks, alcoholic beverages, margarine and edible oil production. The production of consumer durable and semi-durable goods, including that of stoves, refrigerators and textiles declined during 1994.

During 1994, the services sector grew by 6 percent compared with 3 percent in 1993. The performance of distribution and transportation paralleled the increased activity observed in physical production. During this year, there was stronger growth in the financial services industry reflecting the establishment of two new banks.

3.5.3 Mining & Quarrying

The output of this sector continued to be encouraging mainly on account of the good performance of the gold industry. Value added increased by 7 percent in 1994.

Gold declaration for 1994 was 375,618 ounces, 65,846 ounces more in comparison to 1993. The increase in declaration arose primarily from OMAI's output of 276,464 ounces compared with 222,676 ounces during 1993. The declared output of diamond declined by 12,141 metric carats or 28 percent compared with 1993 level to reach 36,792 carats. This may have been the result of a decline in quality and size of diamonds found and the consequent lower returns to diamond mining relative to gold mining.

3.5.4 Construction

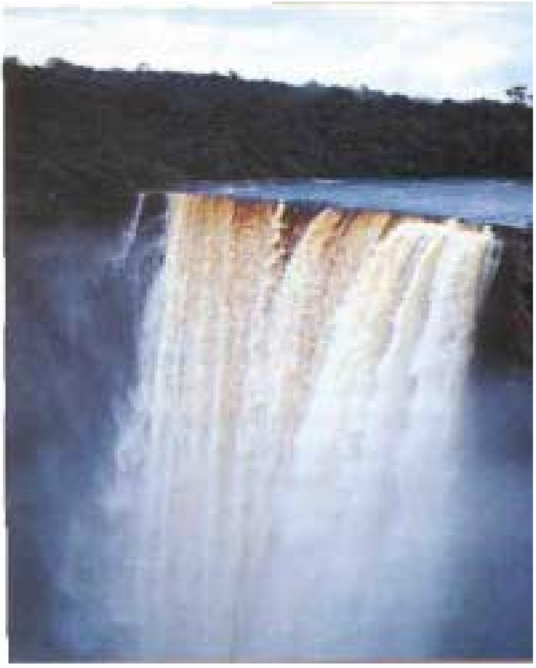
Available data on application for new residential housing, developments in road building, trends in cement imports and production of stone all support the 20 percent expansion in the construction sector during 1994.

3.5.6 Tourism

Guyana possesses a vast interior area, that is pristine, and untouched forests that are so diverse they can show the entire spectrum of tropical rainforest at its best. The potential for a thriving Eco-tourism industry is promising but several key constraints to the sector's development must first be addressed. In 1994, one hundred and thirteen thousand visitors arrived in Guyana. New efforts are now directed towards attracting more visitors to the country.

Guyana will continue to promote its 276 waterfalls including the Kaieteur Falls, with a sheer-drop height of 225 meters. This fall is located in thick jungle in the hinterland but is easily reached by small aircraft, which are chartered by travel agencies.

The Orinduik Falls is a cataract of ten, visited by vacationers. The Ireng River, which forms the border between Guyana and Brazil, thunders over steps and terraces of solid jasper. In the distance is the Pakarima Mountain.



The Kaieteur Falls

In the Savannah plains of the Rupununi, riding, hunting, fishing and swimming are available. There are several tourist lodges in the hinterland and on the banks of Guyana's main rivers.

3.6 ENERGY

The energy sector is receiving extensive focus from the government because energy is seen as an important driving force for growth and development. Consequently, there was a preparation of a National Energy Policy in 1994. The objectives of this policy are to provide stable, reliable and economic supply of energy; to reduce dependency on imported fuels; to promote, where possible, the increased utilization of domestic resources; to ensure that energy is used in an environmentally sound and sustainable manner. The National Energy Policy is supplemented by a National Development Strategy Chapter on Energy. In Guyana the primary sources of energy are petroleum products, bagasse and fuelwood. Currently all petroleum products are being imported. Fuel and lubricant imports accounted for 16 percent of the total imports of 1994.

3.6.1 Imported Petroleum

Imported petroleum, taken together, form the major source of energy in Guyana. Seven products were imported in 1994. These were leaded gasoline, unleaded gasoline, dual-purpose kerosene, diesel/gasoil, No.6 fuel oil (Bunker 'C'), Liquefied Petroleum Gas (LPG) and aviation fuel.

3.6.2 Bagasse and Fuelwood

The other main sources of energy in Guyana are bagasse, a by-product of sugar production, and fuelwood. Bagasse is used for the co-generation of steam and electricity in the sugar industry. Fuelwood becomes available from direct forest harvesting, timber industry waste, ‘slash and burn’ operations associated with land clearing for agriculture, and from self gathering. Some types of woods are transformed into charcoal.

3.6.3 Other Sources

Guyana is well endowed with other indigenous energy resources, apart from bagasse and fuel-wood. With its many rivers and waterfalls, the country has significant hydropower potential. Construction of the Moco-

Moco hydro power station has been completed and it is operational with an installed capacity of (2*250 kW), and annual energy of (3*10) kWh. The power will be transmitted from Moco-Moco via a 13.8kv transmission line to Lethem and the surrounding communities.

In order to further the development of the Energy Sector, a letter of intent was signed for the Tumatumari Hydro power project on March 5, 1998. The installed capacity is expected to be 45MW. The power will be transmitted to the load center at Omai Gold Mines Limited. For the Amaila Hydropower project, a Memorandum of Understanding for a feasibility study was signed on April 24, 1998. This project, when implemented, will produce under 106 MW in the first place. Hydropower is estimated to be in the region of 7000 MW and is seen as a potential source of energy in the long run.

ELECTRICITY GENERATION
INSTALLED CAPACITY OF MAJOR PRODUCERS

Guyana Electricity Corporation	-	130.MW
Linden Mining Enterprise	-	25.0MW
Berbice Mining Enterprise	-	6.0MW
Guyana Sugar Corporation	-	30.6MW
Omai Gold Mines	-	47.0MW

Source: G.E.A. Bulletin, 1997.

Rice chaff also has considerable potential as a source of energy but currently minimal use is being made of this resource. Animal waste is used to generate biogas. There are approximately 10 operational biogas plants in the country.

Wind so far plays an extremely small part in the energy spectrum. Small-scale application is being encouraged. A feasibility study is necessary to determine its viability.

Solar energy is still being promoted in the hinterland areas of Guyana. Photovoltaics systems are being increasingly used mainly by hospitals for lighting and refrigeration. There are other plans for the increased use and development of other supplies of energy sources. Total electricity generation capacity in Guyana is placed in the vicinity of 300 MW.

3.7 TRANSPORTATION

The transportation sector can be divided into three main categories namely: land, air and water. A number of factors (such as increased availability of credit facilities and easy access to suppliers), have led to more persons being able to acquire their own vehicles. Consequently, there has been an increase in the number of registered vehicles in 1994 to 6898 from 6535 in 1993.

DISTRIBUTION OF VEHICLES, 1994

Type of Vehicle	Number
Private Cars	1821
Hire Cars	236
Lorries	676
Buses	850
Station Wagon[1]	153
Vans	301
Tractors	699
Trailers	258
Motor Cycles	1801
Others[2]	103

Source: Guyana Statistical Bulletin, December 1997.

[1] Includes Station Wagons, Land Cruisers and Land Rovers.
[2] Includes Trucks, Jeeps, Pick-ups, Articulate Vehicles, Water Tenders and Hearses.

3.8 LAND USE AND FORESTRY

3.8.1 Land Use

Guyana's coast accounts for almost all of the commercial agriculture and the hinterland contains the vast natural resource wealth of the country. Three quarters of the country, or 164,500 km^2, are covered by tropical moist evergreen rainforest, containing over 1,000 known species.

The hinterland is also rich in minerals. Being part of the Pre-Cambrian shield, the western area has rich deposits of gold and diamonds, with the south and center having good mining potential also. Large deposits of bauxite and kaolin are found in the southeast – northwest belt just behind the coast. Petroleum is also known to exist in scattered locations.

The hinterland possesses many waterfalls with potential for hydroelectric power generation. This area is also rich in biodiversity, with thousands of species of flora and fauna, which exist in a pristine environment. This, together with the magnificent waterfalls and varied topography, lend itself to almost limitless eco-tourism potential.

3.8.1.1 Spatial Pattern of Land Use

Guyana has a very low overall population density – less than 4 persons per km^2. However, the spatial pattern of the population and development is not uniform. The spatial distribution of natural resources, the pattern of climate sub-regimes and the pattern of resource utilization have influenced the geography of population, settlement and development. About 90 percent of the country's population live on the coastal plain, with occupations tied to agriculture in the rural areas, and manufacturing and services in the urban areas. This relatively small strip of land has therefore been the recipient of most of the physical and social infrastructural development of the country, and has become the geographic locus of economic and political power.

The remainder of the population live and work in the hinterland, where the vast wealth of the country lies. Most of the hinterland wage earners are employed in logging, saw milling, gold, bauxite mining and processing and cattle ranching.

Most of the hinterland residents are Amerindians who number some 45,000 and are spread among some 150 villages. Characteristically traditional in lifestyle, this segment of the population has fallen out of stride with mainstream development. The principal economic activity in these areas is mixed subsistence farming. Some communities, particularly those in proximity to mining or forestry operations, have been turning to wage labor.

3.8.1.2 Status of Land Use Planning

National land use planning was limited in Guyana. Land-use planning in relation to human settlements on the coast was being practised. However, with the upswing in the economy in the last few years, and the concomitant agricultural expansion and increase in natural resources utilization, several problems have manifested themselves:

- Illegal resources extraction
- Inadequate coordination of land use policies and regulations
- Multiple use conflicts both in the hinterland and on the coast
- Environmental degradation and pollution

Government, in recognition of this situation, engaged two major efforts.

In 1994 the Government of Guyana and the Federal Republic of Germany entered into a technical cooperation agreement for the establishment of a Natural Resources Management Project (NRMP). This project has several components including the building of institutional and human capacity, legislative reform and land use planning, utilizing a Geographic Information System (GIS). Under the land use planning component, a Geographic Information System (GIS) for natural resources management has been established, and a Land Use Action Plan has been prepared.

At the present time, work is under way to perform a pilot regional land use planning exercise. This exercise is intended to produce a regional level land use plan, and to distill a planning methodology that can be utilized in other regions of the country.

Secondly, the land-use planning component of the NRMP also had a provision for groundwork studies aimed at laying the foundation for development of land use policy. In 1995, the Government of Guyana, the University of Guyana, The Guyana Environmental Monitoring and Conservation Organization, World Resources Institute and the Carter Center came together as the key partners on a project aimed at producing a baseline land use policy document for the Government of Guyana.
Under this project a baseline document was prepared under the guidance of a broad-based National Steering Committee, and benefited from countrywide stakeholder consultations.
In 1996, the final version of the baseline document was completed and presented to Government.

With the land use baseline report completed and a pilot land use planning process in progress, a decision has been taken to expedite the preparation of a national land use policy. This process will utilise existing, approved policies and strategies and useful outputs from the NRMP.

While policies have been formulated at the sectoral level, a comprehensive national land use policy had eluded previous administrations. Under ideal circumstances, a land use policy guides the formulation or amendment of sectoral policies. In Guyana, as in many other countries, development often tended to precede a national land use policy. Given this situation, a conscious strategy has been adopted whereby the land use policy will recognize and be consistent with all existing and recently approved sector policies and strategies, and will also set the stage for informing future policy development in all related sectors.

3.8.2 Forestry

Guyana is at the heart of the Guiana Shield, contiguous to the Amazon Basin and represents one of the best, conserved areas of the region. Approximately seventy-six percent (76%) of Guyana's land area, is covered with forest. Of this, 135,800 km^2 is classified as State Forest. The remainder is classified as State Lands, Amerindian lands, and private property. Approximately 47 per cent of the State Forests have been allocated to logging concessions, in a zone parallel to the coast.

Guyana's forest types include rain forest, seasonal forest, dry evergreen forest, marsh forest, swamp forest, montane forest, and mangrove forest. Guyana has over 1000 tree species, thousands of other plant species and innumerable animal species. Selective logging has been the traditional approach to timber harvesting, where an identified number of commercial species above a specific diameter breast height (DBH) are extracted per hectare with little effect on the forest canopy.

Forestry, along with rice, sugar, fisheries, bauxite, gold and diamond mining, constitute the main components of the economy as sources of foreign currency earnings. In 1994, forestry contributed 4.42 percent of Gross Domestic Product. The performance of the forestry sector has continued to improve significantly. The average contribution of the forest sector to GDP for the period 1994 to 1997 was 4.69 per cent, as compared with the average for the preceding 5 years of 2.29 per cent. The improved performance in the sector is due primarily to an increase in plywood exports as a result of foreign owned Barama Company Limited entering the industry in 1992.

3.9. BIODIVERSITY

While Guyana is one of the smaller countries of the wider Amazon region, it contributes significantly to the biodiversity, both in terms of number of species and number of endemics. Its natural ecosystems are relatively intact due mainly to low population pressure and to limited commercial activity. The importance of the Amazon basin lies in its holding of more than half of the world's biodiversity, its collective magnitude of endemism, its role in ameliorating global climate and in the hydrology of a large part of South America.

There is insufficient knowledge of Guyana's biodiversity richness, but it is relatively safe to suggest that this has been well preserved/conserved. However, current increase in entrepreneurial activity in the natural resources sectors places pressure on the biological resource base and raises real possibilities of increased threat to biodiversity. This is even more critical based on our limited knowledge of our animal species, some of which may be threatened with extinction. Present initiatives, such as the National Wildlife Surveys are intended to provide relevant data required to serve as a guide in the effective management of this resource. Additionally, there are some plant species that are rare but current information in relation to their status is not available.

Recent policies and practices in Guyana are leading to the building of a tradition in support of participatory decision–making and establishment of a policy to conserve and sustainably use the country's natural resources. These policies are reflected at the international level in the signing of a number of international and regional treaties, conventions and other instruments relating to the conservation and sustainable use of natural resources. In keeping with this, Cabinet recently approved a National Biodiversity Plan, which seeks to promote conservation and sustainable use of Guyana's biodiversity. In addition, the continued strengthening of the Environmental Protection Agency must be seen as a concerted effort to ensure the conservation of Guyana's rich biodiversity.

3.10 INSTITUTIONAL ARRANGEMENTS FOR GHG INVENTORY PREPARATION

3.10.1 Existing Arrangements

The President of Guyana has the mandate for environmental issues including climate change. There is an Adviser to the President on the environment who reports to him on climate change matters.

A Natural Resources and Environment Advisory Committee (NREAC) which comprises of the heads of the relevant agencies is chaired by the Adviser to the President. All Climate Change matters are discussed at this committee level before being taken to the President or Cabinet.

The National Climate Committee (NCC) oversees all activities relating to Climate, ozone depletion and desertification and reports to the Chairman of the NREAC. Its current chairman is the Chief Hydrometeorological Officer and its membership comprises all agencies which are relevant to climate issues.

Data gathering was accomplished by the staff of the Enabling Activity Project mentioned in the Introduction Chapter while the GEA provided relevant data for energy sector

3.10.2 Deficiencies in Institutional Strengthening

The Environmental Protection Agency is responsible for co-ordinating activities related to environment protection. The Office of the President is the focal point for the climate conventions and has the responsibility to ensure that Guyana complies with its commitments under the Conventions. However, staff, equipment and other resources must be provided

The sector agencies also do not have staff and/or equipment to do the required tasks. In the current situation staff on routine non-climate change assignments, are asked to take on the additional responsibilities.

In order to put in place an institutional arrangement which will permit inventory preparation on a continuous basis, the following should be done:

- Establish a unit in an existing department/agency to address Guyana's commitments to the Convention and to coordinate the Country's Programme to adapt and to mitigate anthropogenic climate change. Provide adequate staff and equipment for this unit.

- Provide a budget for data collection in each sector agency to deal with inventory data collection and analyses.

- Provide computer systems and relevant software to each sector agency so that the inventory can be computerized. Also ensure a networking system between the unit in the lead agency and the units in the sector agencies so that data can be efficiently transferred.

- Provide training for staff in the lead agency and in sector agencies in GHG Inventory, Vulnerability Analysis and Mitigation Analysis.

CHAPTER FOUR

NATIONAL INVENTORY OF GREENHOUSE GASES

The Convention requires Parties to make periodic reports on national inventory of greenhouse gases. Guyana utilized the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories and considered carbon dioxide, methane, nitrous oxide, non-methane volatile organic compounds, carbon monoxide and nitrogen oxides in its inventory. 1994 was taken as the base year for Guyana.

4.0 NATIONAL INVENTORY OF GREENHOUSE GASES

4.1 INTRODUCTION

In accordance with articles 4.1 (a) and 12.1 (a) of the United Nations Framework Convention on Climate Change (UNFCCC), all Parties to the Convention are obliged to report on and periodically update their national inventory of anthropogenic emissions by sources, and removals, by sinks, of greenhouse gases (GHG) to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of Parties (COP).

As a consequence, the Government of Guyana conducted an inventory of the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Other indirect greenhouse gases, for example non-methane volatile organic compounds (NMVOC), carbon monoxide (CO), and nitrogen oxides (NO_x) were also inventoried to the extent possible.

The IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories, together with the accompanying software, were used to generate the emissions balance. Default values for emission and other factors provided in the Workbook, were extensively used. Because the IPCC software requires land cover to be expressed in hectares (ha), this chapter utilizes hectare as the unit for aerial cover.

Inventories were done separately for the years 1990 through 1998, but the year 1994 was chosen as the base year for the inventory period in accordance with paragraph 14 of the annex to COP Decision 10/CP.2.

It should be noted that CO_2 emissions from **International Bunkers** and **Biomass** are not included in the national totals; they are reported separately as other sources of emissions under **Memo Items**.

The GHG **Inventory** was done on a sector basis for **Energy, Industrial Processes, Agriculture, Land Use Change and Forestry and Waste**. The **Solvents** sector was not considered since the IPCC methodology for this sector is not yet available.

4.2 ENERGY SECTOR

There is no primary/secondary fossil fuel production in the Co-operative Republic of Guyana. Secondary fuels, including gas oil/diesel, kerosene, jet kerosene, Liquefied Petroleum Gas (LPG), gasoline and heavy fuel oil, are imported for local consumption. Fuel imports for international aviation and marine bunkers represent a very small percentage of total imports.

Energy is produced through the combustion of these secondary fuels for use in the power-generating utilities, transport, agriculture/fishing, manufacturing, commercial, residential and tourism and international aviation and marine sectors.

Energy from biomass also accounts for part of the energy sources in Guyana. *Bagasse* is used in the sugar industry and *rice husk* in the rice industry for the co-generation of heat and electricity, while *wood (firewood and charcoal)* is used in the residential sector for cooking purposes.

Methodology

Both the aggregate **Reference Approach** (top-down) and the source categories **Sectoral Approach** (bottom-up) were used to calculate the GHG Inventory for the Energy sector.

Conversion factors derived from the " Latin American Energy Organisation (OLADE)" were used to convert local activity data on fossil fuels, which were expressed in 1,000's of barrels, to **Apparent Consumption** in terajoules (TJ).
Biomass fuels (in 1,000's kg) on the other hand, were converted to Apparent Consumption in TJ by using

the IPCC default values (refer to table 1-13, Vol.3 of the IPCC Guidelines).

In all cases, for lack of country-specific data, the **Default Values of the Conversion, Emission and Carbon Oxidation Factors** as furnished by the IPCC, when available, were used.

CO_2 emissions from fuel combustion for the years 1990 to 1993 were calculated using the **Reference Approach** only, since the relevant data was not available for the period 1990 to 1993 to do the **Sectoral Approach**.

For the years 1994 to 1998, both the top-down **Reference** and the bottom-up **Sectoral** approaches were used to calculate the emissions mainly to assess the effectiveness of the sectoral approach.

The Guyana Energy Agency (GEA) provided the relevant data to enable the use of the Sectoral Approach. This was based on data availability for some sectors (e.g. Energy Industries), and expert estimates for other sectors where specific consumption data were not available. This procedure allowed for obtaining the requisite data on 'sector fuel consumption'. Moreover, this method should give close emission estimates for the various sectors since Guyana's fuel consumption is limited to only six fuel types, and each fuel type is used in a particular sector (e.g. gasoline is used particularly in the **transport** sector). In addition, no fuel is allotted to manufactured items in which carbon is stored since all fuels imported is burnt and carbon storage in products is negligible.

Some differences exist when comparing CO_2 emissions for the **Reference** and **Sectoral** approaches. These differences, which vary from year to year, could have arisen from the procedures used to disaggregate the fuels, as explained above.

Carbon Dioxide emissions/removal

Combustion of fossil and biomass fuels are the two main sources for emissions of CO_2 in the Energy sector. Guyana does not produce cement, which is a very significant source of this gas through its production process. In addition, the country does not have metal producing industries and other industries that emit CO_2 through their production processes. Gold is being produced, but the production process (electrolysis) does not emit CO_2.

CO_2 is the major greenhouse gas being emitted from anthropogenic sources of which a major part is contributed by energy-related activities. For example, in 1994 it represented 96.5% or 1446 Gg (excluding CO_2 emissions from biomass) of the total emissions of CO_2, CH_4 and N_2O, the major GHG's. This percentage share is similar for the other years, 1995 to 1998 for which the sectoral approach was done.

Figure 4.1: Proportion of CO_2 emissions by sub-sectors within Energy sector for 1994.

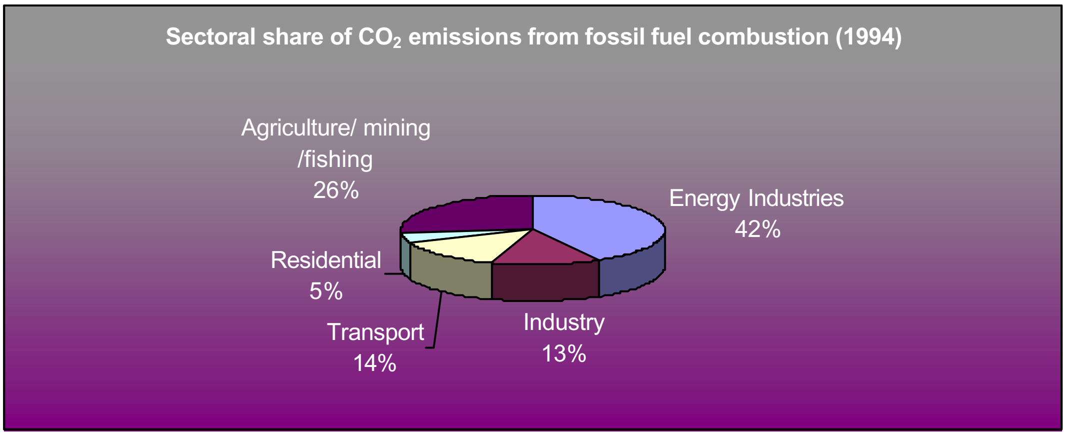


Figure 4.2: Proportion of CO_2 emissions by sub-sectors within Energy sector for 1998.

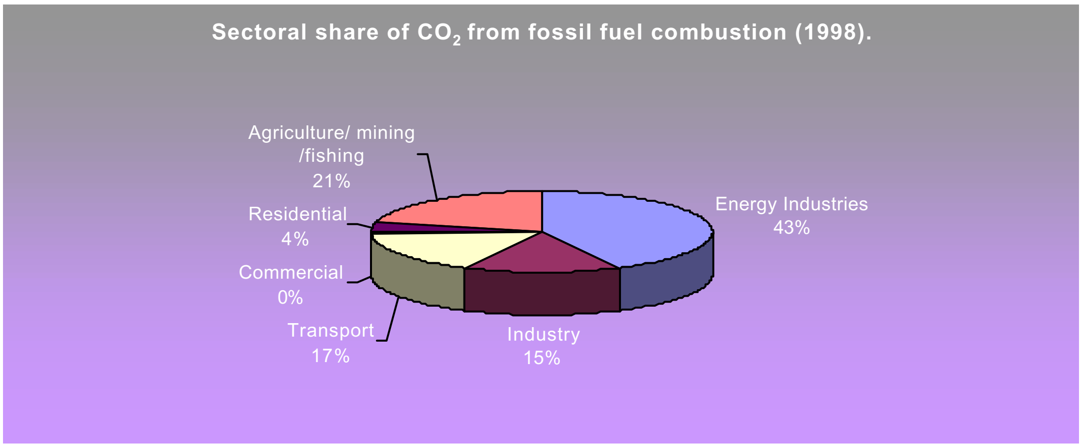


Figure 4.3: CO_2 emissions (Gg) by sub-sectors within Energy sector for 1994 and 1998.

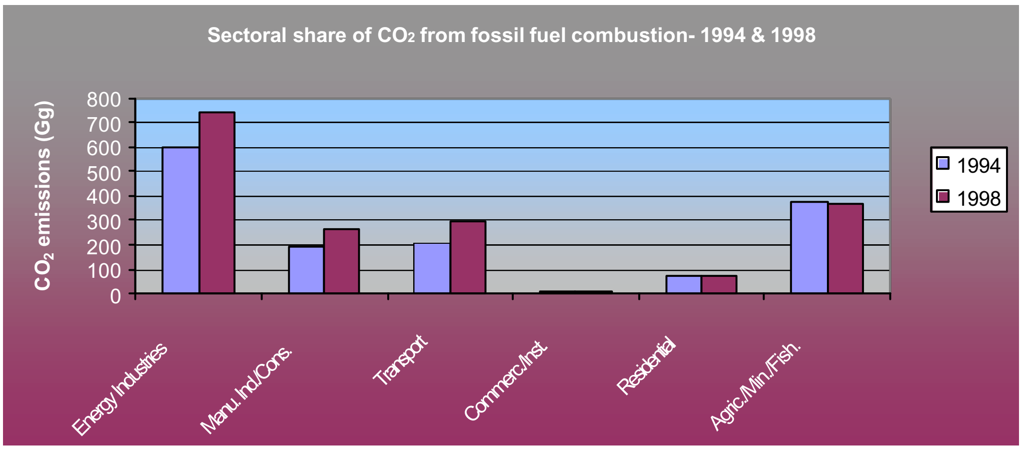


Table 4.1. CO_2 emissions (Gg) from fossil fuel combustion according to the Reference and Sectoral

4.0 NATIONAL INVENTORY OF GREENHOUSE GASES

Approaches.

Year	1990	1991	1992	1993	**1994**	1995	1996	1997	1998
Reference Approach	1198	1218	1266	1320	**1414**	1511	1559	1701	1728
Sectoral Approach	_	_	_	_	**1446**	1469	1538	1663	1749
% Change from 1994 (RA) base value.	- 15	- 14	- 10	- 7		7	9	20	22
Difference between (RA) & (SA) – in (Gg).					**-32**	+42	+21	+38	-21
% difference between (RA) & (SA)					**-2.3**	2.8	1.3	2.2	-1.2

KEY:
1. (RA) – Reference Approach
2. (SA) – Sectoral Approach
3. For Reference Approach data for 1994, see Annex 4.A.

Data analysis of CO_2 emissions for Guyana for the years 1990 to 1998, using both the **Reference** and **Sectoral** approaches show that for the reference year **1994**, CO_2 emissions totaled **1414 Gg** (Reference) and **1446** Gg (Sectoral), a difference of 2.3 %, which is acceptable. However**, the differences are greater for the years, 1995 and less for 1996, 1997 and 1998**, for which both calculations are done, this most likely being due to the estimation of the fuels allocation to the different sub-sectors. ***Also, CO_2 emissions increase by about 15 %, from 1990 to 1994**, **and by a further 21 % from 1994 to 1998***, reflecting an increase in use of fossil fuels through economic growth and expansion (See Table 4.1.)

Table 4.2. CO_2 emissions by sub-sectors within the Energy sector in 1994 –1998

Fuel combustion activities	**1994**		**1995**		**1996**		**1997**		**1998**	
	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
Energy Industries	602	42%	561	38	587	38.3	713	42.9	742	42.4
Manufacturing Indus./Cons.	191	13	178	12	202	13.2	187	11.2	264	15.1
Transport	203	14	204	14	253	16.4	257	15.5	296	16.9
Commercial/Institutional	4	0.3	4	0.3	4.5	0.3	5	0.3	5	0.3
Residential	72.8	5	85.2	5.7	79	5.1	92	5.5	74.3	4.3
Agriculture/Mining/Fishing	373	25.7	437	30	413	26.7	409	24.6	367	21
Total emissions	**1446**	**100**	**1469**	**100**	**1538**	**100**	**1663**	**100**	**1748**	**100**

N.B. Energy Industries include both auto and public generation of electricity

Furthermore, within the **Energy sector**, **CO_2 emissions from *energy industries*** totaled ***602 Gg of CO_2 in 1994***, which accounts for ***42 %*** of the total CO_2 emissions. This figure is consistent from 1994 to 1998. Next in line are CO_2 emissions from ***agriculture, mining and fishing*** that accounted for ***373 Gg of CO_2 (25.7 %)***

in 1994 and ***437 Gg CO_2 (30 %) in 1995***. Other important emitters of CO_2 in the Energy sector are the ***manufacturing industries*** sub-sector that accounted for ***191 Gg of CO_2 (13 %) in 1994*** and ***264 Gg of CO_2 (15.1 %) in 1998*** while the ***transport*** sub-sector emitted ***203 Gg of CO_2 (14 %) in 1994*** and ***296 Gg of CO_2 (16.9 %) in 1998***. See Table 4.2 and Figures 4.1,4.2 and 4.3.

Memo Items

Under the current IPCC methodology, countries are not required to incorporate **Memo Items** including **international aviation and international marine bunkers** and the **burning of biomass** in their total emissions or removals of CO_2. However, countries are obliged to report these items separately.

The Guyana Sugar Corporation uses bagasse for the co-generation of steam and electricity, but these emissions are reported under **Biomass Emissions.** This is because, according to the IPCC, the CO_2 emitted is reabsorbed in the next growing season of sugar cane. This justification applies for all biomass fuels, which are used as a source of energy. Emissions from biomass are therefore reported for information purposes only.

Carbon Dioxide emissions from international bunkers

Emissions from **international bunkers** are very minimal. This is because most of the vessels engaged in international air and marine transport purchased their fuel outside of Guyana. The Guyana Airways Corporation (previously state-owned and presently privatized) was the main consumer of bunker fuel (aviation / jet kerosene).

Table 4.3: CO_2 emissions (Gg) from Memo Items : 1994 to 1998.

Memo Items	1994	1995	1996	1997	1998
International Aviation Bunkers	24	26	23	22	14
International Marine Bunkers	4	4	5	9	7
Total	28	30	28	31	21

CO_2 emissions for the reference year 1994 and more recently for 1998 from **international bunkers** show a sharp reduction in emissions. In 1994, *international air transport* accounted for *24 Gg* of CO_2 emissions while the figure in 1998 was only *14 Gg*. The reduction of CO_2 emissions in 1998 was due to the fact that the national airline, Guyana Airways Corporation, had reduced operations in that year (See Table 4.3).

On the other hand, *international marine transport* showed an increase of CO_2 emissions from only *4 Gg* in 1994 to *7 Gg* in 1998 (See Table 4.3).

CO_2 emissions from biomass fuels

In Guyana the biomass fuels that are burned for energy are primarily firewood, charcoal, bagasse and rice husks.

Table 4.4 gives **total biomass fuel consumption** (metric tonnes) for firewood, charcoal, rice husk and bagasse for the years 1994 to 1998.

Table 4.4 Biomass fuel consumption by types (metric tonnes).

	Year				
Consumption (boe)	**1994**	**1995**	**1996**	**1997**	**1998**
Firewood	82436.0	83200.0	85591.0	87352.0	87011.0
Charcoal	1691.0	1448.0	1081.0	587.0	601.0
Bagasse	1132938.0	1418432.9	1199591.0	1516676.2	1090084.0
Rice husk	40000.0	40000.0	45000.0	54000.0	60000.0
Total	**1257065.0**	**1543080.9**	**1331263.0**	**1658615.2**	**1237696.0**
Source: Guyana Energy Agency.					

For the reference year, 1994, the largest amounts of CO_2 emissions derive from **bagasse** combustion (983.7 Gg) in the **energy industry** sub-sector. Smaller amounts derive from the combustion of wood and wood wastes in the **residential** (98.48 Gg), **manufacturing** (45.73 Gg) and **rice husk** in the **manufacturing** (62.52 Gg) sub-sectors. **Charcoal** combustion in the **residential** sector only accounts for 5.32 Gg of CO_2 emissions (See Table 4.5 for details).

Table 4.5: CO_2 emissions from biomass (Gg) in 1994.

Biomass Type	Energy Sub-sector	Residential Sub-sector	Manufacturing Sub-sector	Commercial Sub-sector	Totals (Gg)
Wood/waste	_	98.48	45.73	4.32	148.52
Bagasse	983.7	_	_	_	983.72
Rice husk	_	_	62.52	_	62.52
Charcoal	_	5.32	_	_	5.32
Total					**1 200.08**

Total CO_2 emissions (Gg) from biomass fuels, namely firewood, charcoal, rice husk and bagasse for the years 1994 to 1998 are relatively stable and consistent being **1200 Gg in 1994**, the reference year, and rising to 1270 Gg in 1996 (See Table 4.6).

Table 4.6: CO_2 emissions from biomass fuel (1994 – 1998) Gg.

Years	**Total Emissions (Gg)**
1994	1200
1995	1157
1996	1270
1997	1248
1998	1199

Non-Carbon Dioxide (CO_2) emissions

Non-CO_2 emissions of **methane** (CH_4), **nitrous Oxide** (N_2O), **nitrogen oxides** (NO_x), **carbon monoxide** (CO) and **non-methane volatile organic compounds** (NMVOC) are relatively small for the Energy sector in Guyana (See Table 4.7). Only **CO** emissions *(44.51 Gg in 1994 and 49.96 Gg in 1998)*, **NOx** emissions *(10.66 Gg in 1994 and 11.91 Gg in 1998)* and **NMVOC** emissions *(6.27 Gg in 1994 and 7.15 Gg in 1998)* seem significant. For instance, in 1994, **CO** emissions derived mainly from fuel combustion in the road transport *(22.4 Gg)* and energy industries *(9.18 Gg)* sub-sectors. **NOx** emissions in 1994 on the other hand, are produced by the mobile fishing *(5.51 Gg)*, energy industries *(2.51 Gg)* and road transport *(1.68 Gg)* sub-sectors.

Table 4.7. Non- CO_2 emissions (Gg) from fuel combustion (fossil & biomass) by source category: 1994 – 1998.

Non-CO_2 GHG	1994	1995	1996	1997	1998
CH_4	0,72	0.71	0.75	0.75	0,74
N_2O	0,06	0.05	0.06	0.06	0,06
NO_X	10.66	11.47	11.69	11.96	11.91
CO	44.51	44.35	47.62	48.61	49.96
NMVOC	6.27	6.30	6.74	6.89	7.15

Fugitive emissions are considered to be zero in Guyana. This is because the country is not involved in activities from which fugitive emissions arise.

4.3 INDUSTRIAL SECTOR

In spite of its geographical size and vast natural resources, Guyana does not have a strong Manufacturing or Industrial sector so that GHG emissions from light manufacturing or heavy industries are minimal. GHG emissions in this sector are limited to **NMVOC** emissions from the **food and beverage industry** and from **asphalt** used in road paving.

Methodology

NMVOC emissions derived from *bitumen used in road paving with asphalt*, and the *manufacture of alcoholic beverages* (rum, beer and stout, shandy and wine) and *food production* (bread, biscuits, meat, fish and poultry, sugar, margarines and stockfeed). All activity data are country-specific and were obtained from the Bureau of Statistics, Guyana. However, all emission factors were taken as Default Values from the IPCC Workbooks.

An average emission factor of (0.057) was used to estimate NMVOC from wine production since production figures were not separated as white and red wine.

NMVOC Emissions

For the inventory year 1994, **NMVOC** emissions from **road paving with asphalt** was **9.60 Gg**, from the manufacture of **alcoholic beverages** it was **3.87 Gg** and from **food production** it was **2.77 Gg** (See Table 4.8)

Table 4.8: NMVOC emissions (Gg) from the Industrial Processes sector in 1990 to 1998.

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998
Road Paving Asphalt	N.E.	N.E.	N.E.	N.E.	**9.60**	N.E.	N.E.	N.E	N.E.
Alcoholic Beverages	2.75	2.45	3.28	3.79	**3.87**	3.39	3.59	3.5	3.31
Food Production	1.49	1.80	2.65	2.66	**2.77**	2.75	3.01	2.97	2.77
Total	**4.24**	**4.25**	**5.93**	**6.45**	**16.24**	**6.14**	**6.6**	**6.47**	**6.08**

Total NMVOC emissions in 1994, the reference year, were relatively high compared to the other years. This was because emissions from *road paving with asphalt* were not estimated for the other years (data not available).

Halocarbon emissions from the consumption, use and disposal of products containing halocarbons, such as refrigerants and air conditioners are not included in the *Inventory*, since these are substances controlled under the Montreal Protocol.

4.4 AGRICULTURE SECTOR

Agriculture is one of the key sectors of the Guyanese economy, accounting for more than 25 % of GDP in 1994. Methane (CH_4) is one of the most important non-CO_2 GHG emitted by the Agriculture sector. **CH_4** emissions are derived from *rice cultivation*, *field burning of agricultural residues*, *prescribed burning of savannahs, and enteric fermentation and manure management* in the rearing of livestock. **CO** and **NO_x** emissions on the other hand are derived exclusively from the *field burning of agricultural residues* and to a lesser extent from *prescribed burning of savannahs.* **N_2O** emissions however, which are very small, resulted from a number of sources, including *enteric fermentation and manure management, field burning of agricultural residues*, *prescribed burning of savannahs* and a variety of soil processes (including synthetic nitrogenous fertilizer application).

Methodology

<u>*Domestic livestock, rice cultivation, field burning of agricultural residues and agricultural soils*</u>

Activity data on rice cultivation, production of crops, and animal population according to species, are country-specific to some extent. Where no data was available locally, estimates from the Food and Agricultural Organisation (FAO) Statistical Yearbook were used. However, emission factors and other default values were taken from the Revised 1996 IPCC Workbook.

For field burning of crop residue, the most important crops for Guyana are rice and sugar cane. Other crops are considered insignificant. Default values for maize were used for sugar cane to do the emissions estimates, while an estimated 70% of the residue in the field is burned.

Derivation of enteric fermentation emission factor for poultry

The IPCC Revised 1996 Workbook does not have an emission factor for the enteric fermentation of poultry. Also, it was not possible for any other reference to be identified and used. It was therefore decided to obtain the emission factor by consideration of the factor for swine, which has been given in the IPCC Workbook.

The ratio of the emission factor for poultry (0.023) to that of swine (2.0) is (0.0115). This value was then assumed to be the ratio of the enteric fermentation for poultry to that of swine. The enteric fermentation for swine was (1.0) which was obtained from the IPCC Revised 1996 Workbook. Therefore, the enteric fermentation emission factor for poultry was calculated to be (0.012) using the values and the assumptions above.

Prescribed burning of savannahs
Two categories of savannah lands were identified: dry and wet savannahs. No data on total savannah area burnt annually was available. As such, the default approach of using the total savannah area and a fraction of what is burnt annually was used to estimate GHG emissions from this source.

Discussions with officials revealed that some spontaneous burning occurs annually. Also, there is some amount of planned burning for agricultural purposes but monitoring of this situation is inadequate. It was determined that the total area burnt annually however, represents a very small percentage of the total savannah area. Within the foregoing context, the default fraction (0.50) for savannah burnt annually in Tropical Region in the IPCC Workbook, significantly overstates the total area of savannah burnt annually in Guyana. A decision was therefore taken to use the value (0.065) in our inventory, which fell in the range of default values for the Sahel Zone, shown in the IPCC GHG Inventory Workbook.

CH_4, CO, N_2O and NO_x Emissions

In 1994, the reference year, **CH_4** emissions in the Agriculture sector amounted to **40.95 Gg**. Of this total, emissions from *domestic livestock* amounted to *14.35 Gg*, with *95.5 %* coming from *enteric fermentation (13. 66 Gg),* and the remainder coming from *manure management (0. 69 Gg)*. *Rice cultivation* is the other major source of CH_4, amounting to *22.33 Gg (44 % of total)* in 1994. A smaller amount, *3.20 Gg* of CH_4, is emitted from the *field burning of agricultural residues* and *1.07 Gg* from *prescribed burning of savannahs* (See Table 4.9).

CO is emitted exclusively from the *field burning of agricultural residues* and *prescribed burning of savannahs*, amounting to **95.27 Gg** in 1994 from the Agriculture sector (See Table 4.9).

N_2O, on the other hand, is emitted from **all agricultural activities** listed in Table 4.9, except *rice cultivation*. However, the amount was **1.16 Gg** in 1994.

NO_x emissions are derived exclusively from the *field burning of agricultural residues*. In 1994, a relatively small amount (**4.04 Gg**) was emitted from the Agriculture sector (See Table 4.9).

Table 4.9: CH_4, CO, N_2O and NO_x emissions (Gg) in the Agriculture sector for 1994.

Activity	CH_4	CO	N_2O	NOx
Enteric Fermentation and Manure Management.	14.35	_	0.01	_
Flooded Rice Cultivation	22.33	_	_	_
Field Burning of Agricultural Residues	3.20	67.21	R.E.	3.56
Direct Nitrous Oxide Emission from Agricultural Fields	_	_	0.39	_
Nitrous Oxide Soil Emissions From Grazing Animals	_	_	0.41	_
Indirect Nitrous Oxide Emissions from Leaching and atmospheric deposition	_	_	0.34	_
Prescribed burning of savannah	1.07	28.06	0.01	0.48
Totals	40.95	95.27	1.16	4.04

R.E. –reported elsewhere (under agricultural fields)

4.5 LAND USE CHANGE AND FORESTRY

Of Guyana's total area of 21.5 million hectares, three quarters of its land surface, representing over 16 million hectares, are covered mainly by tropical moist evergreen rainforests, containing over 1,000 known species.

Available data and expert estimations from the Guyana Forestry Commission place Guyana's forested area (total **area: 16.45 million hectares**), which is **impacted by anthropogenic activities at an estimated 2.273 million hectares** (1998). This total disturbed forest area is based to a large extent on a percentage of the total forest area that is allocated to logging, an anthropogenic activity that disturb/impact on the forest biomass stocks. It includes the categories **Wood Cutting Leases, Timber Sales Agreements (TSA) and State Forest Production (SFP) conversion areas (Total forest area impacted from logging: 2,182,152 ha).** The disturbed forest area from **mining activities (40,000 ha) and from land allocated to Amerindian communities (51,000 ha)** were also crudely estimated and used in the inventory. This estimated disturbed-forest area acts as a sink for CO_2 through natural regeneration.

Methodology

Changes in forest and other woody biomass stocks & Forest Conversion

Activity data on **species and areas** (hectares) of forest/biomass stocks of forests and on **commercial harvest** from the forest (m^3) are country-specific and were obtained from the **Guyana Forestry Commission** and to a limited extent from the **FAO Statistical Yearbook.** However, **annual growth rate (tdm/ha), conversion** and **emission** factors relating to **carbon fraction**, **biomass conversion/expansion** and **fraction of biomass oxidized** were taken as **default** values from the **IPCC Workbooks**. Furthermore, where published data was lacking, as for instance the fraction of biomass burned on-site and off-site, these were estimated, based on expert judgement, from comparisons with other countries in the region (eg. Costa Rica).

Because of a lack of data locally on forest conversion, the estimates for the rate of conversion of forest as provided in the Revised 1996 IPCC GHG Inventory Workbook (1980-1990 period) was used in this inventory as default.

Abandonment of Managed Lands

No data is available for the Abandonment of Managed Lands in Guyana. However, based on expert judgement, this value is insignificant.

CO_2 Emissions / Removals

CO_2 emissions and **removals** from **the Land Use Change and Forestry** sector are derived from anthropogenic depletion in forest and other woody biomass stocks leading to **removal** of CO_2 from carbon uptake, as a result of biomass regrowth from the conversion of forests and grasslands, and **emissions** from forest and grassland conversion due to burning and decaying of biomass.

The Land Use and Forestry data analyzed for the reference year, 1994, show a **gross removal (-29,195.35 Gg)** of CO_2 due to growth **changes in forest and other woody biomass stocks.**

This apparently large annual sink is due to two reasons:

(1) *Uncertainties in acquiring and using activity data:* The absence of country-specific activity data, particularly the annual growth rate of the forest led to the use of the IPCC default value, which may be unreliable. The IPCC Guideline was also not clear on the definition of a "managed forest", and further, the managed area of which was crudely estimated.

(2) *Inadequacy of the IPCC Methodology:* The calculation of CO_2 uptake is dealt with on a yearly basis. Hence, the emission from forestry production (3-year average) for the inventory year (under the assumption that all biomass extracted from the forest is oxidised in the year of production) is subtracted from the carbon uptake resulting from regrowth of the forest. The large resulting uptake of CO_2 is as a consequence of regrowth of the total managed forest area as at the year of calculation (estimated), that is, it included regrowth of forest that was anthropogenically impacted prior to the inventory year.

On the other hand, **forest and grassland conversions** account for **2,530.88 Gg of CO_2** emitted through burning and decaying of biomass. This results in a **net removal/sink (-26,664.47 Gg) of CO_2 from Land Use Change and Forestry** in Guyana (See Table 4.10 and Figure 4.4).

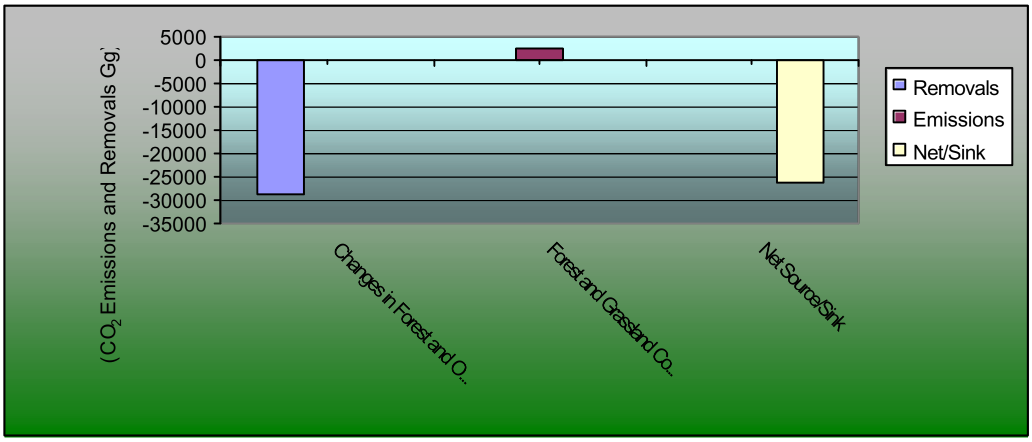
Removal of CO_2 as a result of regrowth from the **abandonment of managed lands** is negligible in Guyana.

Table 4.10: CO_2 emissions, removals and net sink (Gg) for Land Use and Forestry sector, 1994.

Activity	Removals	Emissions	Net / Sink
Changes in Forest and Other woody Biomass stocks	-29,195.35	_	_
Forest and Grassland Conversion	_	2,530.88	_
Carbon Uptake from Abandonment of Managed Lands	N.E	N.E	N.E
Net Source / Sink	_	_	-26,664.47
Total	**-29,195.35**	**2,530.88**	**-26,664.47**

N.E. (Not Estimated)

Figure 4.4: CO_2 emission, removals and net sink (Gg) from Land Use and Forestry sector, 1994.



Trace Gas Emissions

Trace gases including **CH_4, CO, N_2O** and **NO_x** are also emitted from the **burning of cleared forests.**

Table 4.11 shows that the most important trace gas emitted from the **burning of cleared forests** is **CO (67.95 Gg)**, with smaller amounts of **CH_4 (7.77 Gg)**, **NO_x (1.93 Gg)** and **N_2O (0.05 Gg)**.

Table 4.11: Trace gas emissions from forest burning (Gg), 1994

Trace Gas	CH_4	CO	N_2O	NO_x
Emissions (Gg)	7.77	67.95	0.05	1.93

4.6 WASTE SECTOR

In the **Waste** sector, GHG emissions are limited to **methane (CH_4)** from **Solid Waste Disposal Sites (SWDS)** and to indirect **nitrous oxide (N_2O)** emissions from **human sewage**.

Solid waste and wastewater handling

Solid Waste disposal on Land

The solid waste disposal on land falls under the categories 'open-dump' and 'sanitary landfill'. Sanitary landfill (managed site), which is described as the trench-method, is particularly practiced in the capital city, Georgetown. The other urban areas practice 'open dumping' (unmanaged sites) where waste is burnt regularly. However, all the urban areas were considered in the inventory.

The rural population, which is about 66% of the total population (782,427: 1998 data), does not have an organized collection and disposal system for solid waste. Most of the waste generated is scattered on the land while part is burnt/buried, rather than being placed at specific locations/sites. Thus, there is little or no methane emission from rural locations.

Methodology

Activity data pertaining to Municipal Solid Waste (MSW) disposed to SWDS's are country-specific with the estimate on urban population obtained from the Bureau of Statistics, Guyana. However, the **IPCC Default** values for **Methane Correction** factor, **Fraction of Degradable Organic Compounds (DOC)** in (MSW), **Fraction of DOC which degrades** and **Fraction of Carbon Released** as methane were used for the estimation of **methane** emissions from solid waste disposal systems. Default values for **India** were used for the estimation of methane emissions from solid waste.

CH_4 Emissions

Data analyses using the above methodology provide **net annual methane emissions, from Solid Waste Disposal Sites, of 1.20 Gg** in 1994 for Guyana (See Table 4.12).

Indirect Nitrous Oxide Emissions from Human Sewage

Only part of the capital city, Georgetown, and the sub-urban district of Tucville have sewerage facilities, representing an estimated 10% of the population of Guyana. Out of the remaining 90% of the population, about 20-30% are estimated to use septic tanks and the remainder use pit latrines.

Methodology

Nitrous oxide (N_2O) emissions from **human sewage** was estimated from country-specific data on **population** as obtained from the Bureau of Statistics, Guyana.

However, the **IPCC default factors** for *fraction of nitrogen in protein* and *emission of N_2O* were used to estimate emissions from **human sewage**.

A factor of 25.8 was used for 'per capita protein consumption' (protein in kg/person/yr) to do the emissions estimates via human sewage. This factor is similar to that used by the Bahamas in their inventory study.

N_2O Emissions

Based on the above analysis, **nitrous oxide (N_2O)** emissions in Guyana were estimated to be **0.05 Gg** in the year 1994. Thus, N_2O emissions from this source are very low (See Table 4.12).

Other sources of N_2O emissions are agricultural activities such as synthetic fertilizer usage and field burning of crop residues. Organic amendments to soil are done on a very small scale and this is particularly related to kitchen gardens. Thus, N_2O emissions from these sources are insignificant.

Table 4.12: CH_4 and N_2O emissions (Gg) from the Waste sector for Guyana in 1994.

Activity	CH_4 Emissions	N_2O Emissions
Solid Waste Disposal on Land	1.20	_
Sewage	_	0.05

Industrial Wastewater

The state-owned Guyana Sugar Corporation, the privately owned beverages and fish processing factories, and the Omai Gold Mines Limited are essentially the companies where industrial wastewater is produced.

The wastewater from these sources is discharged into flowing rivers/the ocean, except Omai Gold Mines Limited where it undergoes a treatment process (both naturally and chemically) for the degradation/reduction of cyanide before discharging into the Essequibo river. There is no anaerobic treatment of industrial wastewater; hence no methane emission was calculated.

Domestic Wastewater Handling

There is no anaerobic treatment of wastewater; hence estimates of methane emissions from domestic wastewater have not been made.

Waste Incineration

A Waste Incinerator is located in the capital city, Georgetown. Primarily waste from the abattoir and hospitals is incinerated here. The IPCC Workbook does not have a methodology to estimate emissions from incinerators so such emissions were not calculated. However, emissions will be negligible since the bulk of solid waste in Guyana is placed in "open dumps/sanitary landfill sites" in the urban centres, and in rural areas where it is scattered on land, burnt/buried. Nevertheless, an attempt can be made to address this in future National Communications.

4.7 SUMMARY OF EMISSIONS AND REMOVALS

A Short Summary of the major emissions by sources and removals by sinks on a sector-by-sector basis for Guyana for the reference year 1994 is provided in Table 4.13 and Figure 4.5.

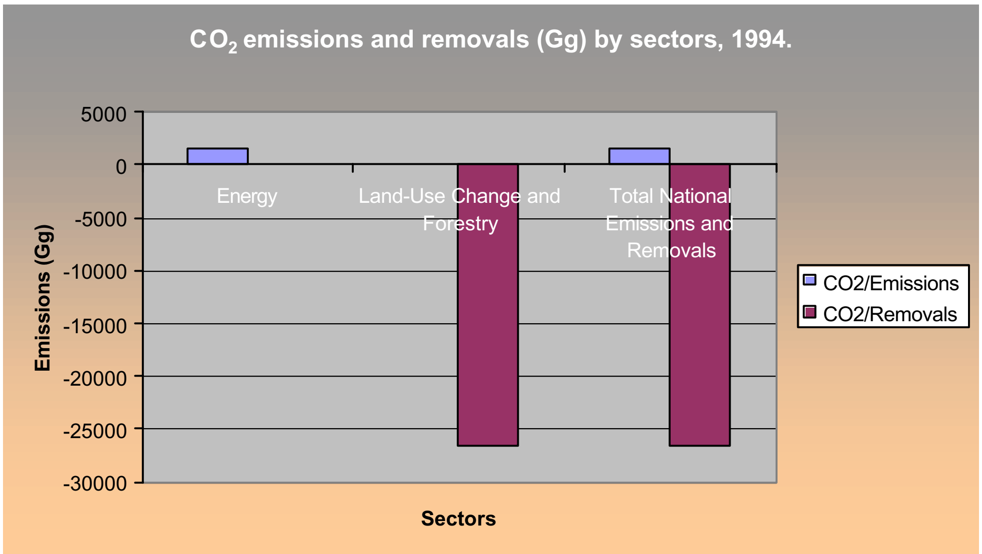
Table 4.13: CO_2 emissions and removals (Gg) by sectors for Guyana, 1994.

Greenhouse Gas Source and Sink Categories	$C0_2$/Emissions	$C0_2$/Removals
Energy	1,446	0
Industrial Processes	0	0
Agriculture	0	0
Land- Use Change and Forestry	(2530.88)	-26, 664.47*
Waste	N.E.	0
Total National Emissions and Removals	**1446**	**-26, 664.47***
Memo Items		
International Bunkers	28	0
$C0_2$ Emissions from Biomass	1200	0

KEY: 1. (N.E. – Not estimated)

2. ( ) - emissions value not counted because this source sector has net removals of CO_2 - IPCC.
3. (*) - value indicated net removal from this sector

Figure 4.5. CO_2 Emissions and Removals (Gg) by Sectors, 1994.



It is evident that the major emitter of CO_2 emissions in 1994 is from the Energy sector (1446 Gg), which virtually accounts for all of the CO_2 emissions, with the exception of Memo Items, biomass burning (1200 Gg) and international bunkers (28 Gg).

The Land Use Change and Forestry sector, which is also responsible for some amount of CO_2 emissions, through forest and grassland conversion (2,530.88 Gg), however is a net sink for CO_2 with a net removal of 26,664.47 Gg for 1994. This value derived from removal by growth *Changes in Forest and Other Woody Biomass Stock* **(-29,195.35 Gg of CO_2)** less emissions from *Forest/Grassland Conversion* - **2,530.88 Gg** (See Table 4.13 and Figure 4.5).

Non- CO_2 emissions /removals

Comparatively smaller amounts of non-CO_2 GHG's are emitted or removed in the year 1994 (See Table 4.14 and Figure 4.6).

CH_4 emissions, which totaled 50.64 Gg, derived mainly from Agriculture (40.95 Gg) and Land Use Change and Forestry (7.77 Gg). Smaller amounts are derived from solid waste disposal in the Waste sector (1.20 Gg), and Energy sector (0.72 Gg).

N_2O emissions on the other hand are restricted to emissions from the Agriculture sector, (1.16 Gg). Emissions from other sectors were negligible: human sewage (0.05 Gg N_2O) in the Waste sector, fuel combustion in the Energy sector (0.06 Gg), and conversion of forest in the Land Use Change and Forestry sector (0.05 Gg). This gives a total of **1.32 Gg** in the year 1994.

NMVOC emissions derive exclusively from *road paving with asphalt* and from *food and beverage production* in the Industrial Processes sector and Energy sector (6.27 Gg), totaling 22.51 Gg in 1994.

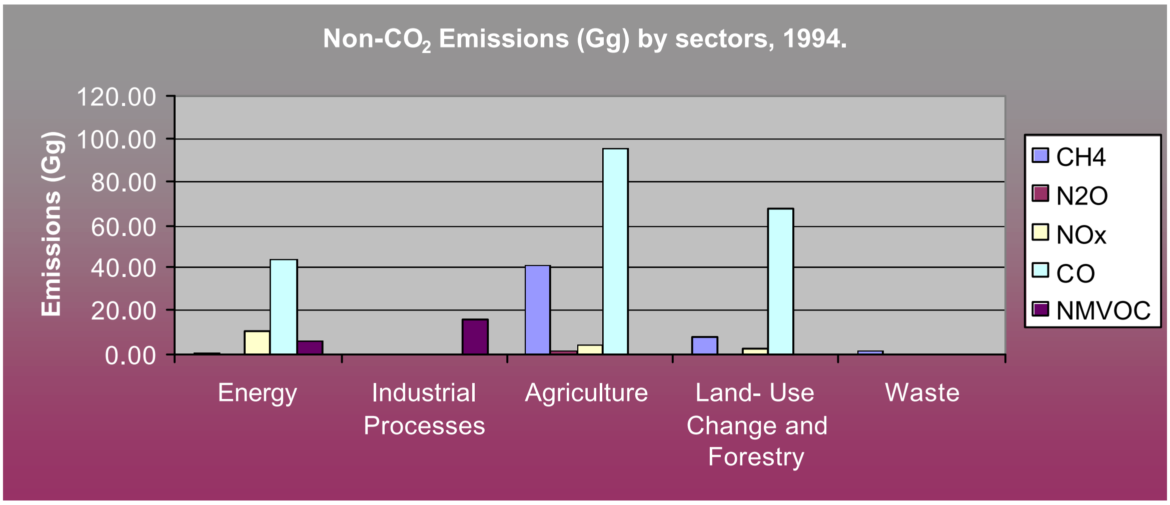
NO_x emissions derive from the Energy sector (10.66 Gg), the Agriculture sector (4.04 Gg) and from the Land Use and Forestry sector (1.93 Gg), totaling **16.63 Gg** in 1994.

CO is emitted in relatively large quantities from the Energy sector (44.51 Gg), from the Agriculture sector (95.27 Gg) and from the Land Use and Forestry sector (67.95 Gg) giving a total of **207.73 Gg** in 1994.

Table 4.14: Non- CO_2 emissions (Gg) by sectors, 1994.

	Emissions (Gg)				
Greenhouse Gas Source and Sink Categories	CH_4	N_2O	NOx	CO	NMVOC
Energy	0.72	0.06	10.66	44.51	6.27
Industrial Processes	0	0	0	0	16.24
Agriculture	40.95	1.16	4.04	67.21	0
Land- Use Change and Forestry	7.77	0.05	1.93	95.27	0
Waste	1.20	0.05	0	0	0
Total National Emissions	**50.64**	**1.32**	**16.63**	**207.73**	**22.51**
Memo Items					
International Bunkers	0	0			0

Figure 4.6: Non-CO_2 emissions and removals (Gg) by sectors.



Global Warming Potential

Global Warming Potential (GWP) provides a simple measure of the relative radiative effects of the emissions of the different GHG's. The GWP index is defined as the cumulative radiative forcing between the present and some chosen time horizon, here taken as 20 and 100 years (see Table 4.15), caused by a unit mass of GHG emitted now, expressed relative to that of the reference GHG, namely CO_2.

The GWP of CO_2, CH_4, and N_2O are provided in table 4.15. GWP's for NO_x, CO and NMVOC are not calculated because this is not currently possible on account of inadequate characterization of many of the atmospheric processes involved.

It is evident in table 4.15 that for Guyana, even taking GWP's into account, the removal of CO_2 mainly by forest sinks (-26,664.47) by far surpasses the CO_2-equivalent emissions (3,651.44 Gg over 20 years and 2,918.64 Gg over 100 years).

Table 4.15: Global Warming Potentials, year 1994.

Greenhouse Gases (GHG)	Lifetime (Years)	Global Warming Potential (Time horizon)		Total Emissions (Gg)	Total Emissions CO_2-Equivalent 20 years (Gg)	Total Emissions CO_2-Equivalent 100 years (Gg)
		20 years	100 years			
Carbon Dioxide (CO_2)	Variable	1	1	1446.00	1,446.00	1446.00
Methane (CH_4)	12(+)/(-)3	56	21	50.64	2,835.84	1,063.44
Nitrous Oxide (N_2O)	120	280	310	1.32	369.60	409.20
Total Emissions (CO_2-Equivalent)				**4,028.84**	**3,651.44**	**2,918.64**
Total Net Removals (CO_2- Equivalent)					**-26,664.47**	**-26,664.47**

Source: IPCC, 1995.

4.8 BASELINE AND TRENDS

The year 1994 was used as the reference year to establish Guyana's emissions by sources and removals by sinks of greenhouse gases. However, for purposes of comparison and to establish trends in GHG emissions for Guyana, this section presents the results of GHG emissions from 1990 to 1998. In addition, trends are established according to the major GHG's, namely, CO_2, CH_4, N_2O and the indirect GHG's NMVOC, CO and NO_X.

CO_2 Emissions

Table 4.16 and Figure 4.7 show the trend in emissions of CO_2 from fossil fuel combustion over the years 1990 to 1998. The indication is that there was a gradual increase from 1990 to 1993 and then an accelerated increase to 1998. Increases in the importation of diesel oil as a result of increased output of electricity and an increase of cultivated land (mainly for rice production) contributed mainly to the increases of CO_2 emissions.

Table 4.16: Total carbon dioxide emissions and removal in 1990 – 1998 (Gg)

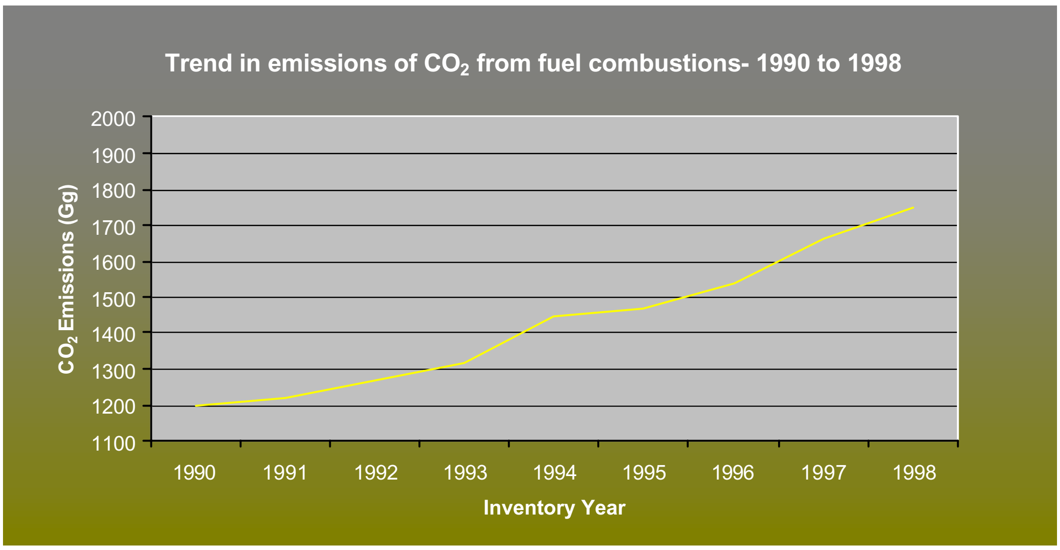
	CO_2 emissions				
	1990*	1991*	1992*	1993*	1994
Fuel combustion	1198	1218	1266	1320	1446
Industrial processes	N.O.	N.O.	N.O.	N.O.	N.O.
Total CO2 emissions	**1198**	**1218**	**1266**	**1320**	**1446**
	CO_2 removal/emissions				
Changes in Forest/Woody Biomass	-26308	-27149	-27918	-28597	-29,195
Forest/Grassland Conversion	2531	2531	2531	2531	2531
Total CO_2 removal	**-23,777**	**-24,618**	**-25,387**	**-26,066**	**-26,664**
	Total national CO_2 emissions balance				
Total emissions balance	-22,579	-23,400	-24,121	-24,746	-25,218

	CO_2 emissions			
	1995	1996	1997	1998
Fuel combustion	1469	1538	1663	1749
Industrial processes	N.O.	N.O.	N.O.	N.O.
Total CO2 emissions	**1469**	**1538**	**1663**	**1749**
	CO_2 removal/emissions			
Changes in Forest/Woody Biomass	-29990	-30954	-31788	-33565
Forest/Grassland Conversion	2531	2531	2531	2531
Total CO_2 removal	**-27459**	**-28423**	**-29257**	**-31034**
	Total national CO_2 emissions balance			
Total emissions balance	-25990	-26885	-27594	-29285

*Determined by IPCC Reference Approach Methodology

Note1: Emissions from lubricants not included for the years 1990-1993 (data not available).
Note 2: Emissions from **biomass and international bunkers** are not included here.
Note 3: Negative values indicate removals.

Fig. 4.7 Trend in emissions of carbon dioxide from fossil fuel combustion – 1990 to 1998 (Gg)



CH_4 Emissions

The main source of CH_4 emissions in Guyana is from agricultural activities, that is, rice cultivation, and rearing of livestock (enteric fermentation & manure management). Methane is also produced from solid waste, combustion of fossil fuel, prescribed burning of savannahs, and forests/grassland conversion.

Methane emissions are very low when expressed in percentage of total emissions of the major greenhouse gases. For example, in 1994 and 1998 the combined total emissions of CO_2, N_2O and CH_4 were 1501 Gg and 1809 Gg (excluding CO_2 emissions from biomass fuel) respectively. Out of these totals, only 3.59% (or 54 Gg) in 1994 and 3.26 % (or 59 Gg) in 1998 were represented as methane emissions.

Table 4.17 and Figure 4.8 provide estimates of methane emissions for the years 1990 to 1998. These show that CH_4 emissions rose from about 40 Gg in 1990 to about 60 Gg in 1998.

Table 4.17: Methane emissions, 1990-1998 (Gg)

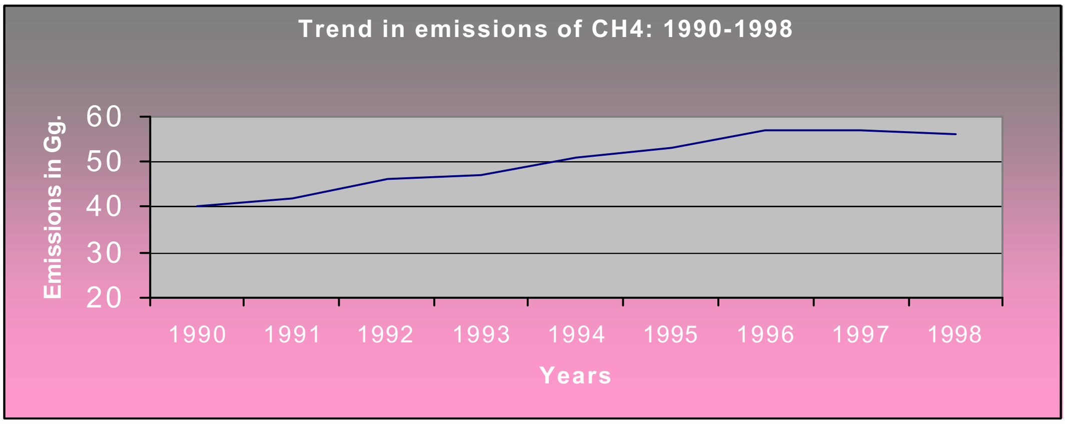
	1990	1991	1992	1993	1994
Fuel comb., total	**N.E**	**N.E**	**N.E**	**N.E**	**1**
Agriculture, total	**31**	**33**	**37**	**39**	**41**
Rice Cultivation	10	14	17	19	22
Enteric Fermentation	17	15	15	15	14
other	4	4	5	5	5
Forestry, total	8	8	8	8	8
Forest Conversion	8	8	8	8	8
Waste, total	**1**	**1**	**1**	**1**	**1**
Solid waste disposal	1	1	1	1	1
Total CH4 Emissions	**40**	**42**	**46**	**48**	**51**

	1995	1996	1997	1998	
Fuel comb. , total	**1**	**1**	**1**	**1**	
Agriculture, total	**44**	**47**	**47**	**46**	0
Rice Cultivation	25	27	27	26	
Enteric Fermentation	14	15	15	15	
other	5	5	5	5	
Forestry, total	8	8	8	8	
Forest Conversion	8	8	8	8	
Waste,total	**1**	**1**	**1**	**1**	0
Solid waste disposal	1	1	1	1	
Total CH4 Emissions	**54**	**57**	**57**	**56**	**0**

Note: 1. **Other** includes emissions from manure management, prescribed burning of savannahs and field burning of agricultural residues.

2. **(N.E.)** - not estimated (relevant data not available).

Figure 4.8: Trend in emissions of CH_4 for the period 1990 to 1998.



From Figure 4.8, it is evident that emissions rose gradually to the year 1996, then remained constant up to 1998. Generally, the increase in CH_4 over the period (1990-1998) was due mainly to the increase in land area cultivated for rice production, a main source for this gas from the anaerobic decomposition of organic material in flooded rice fields.

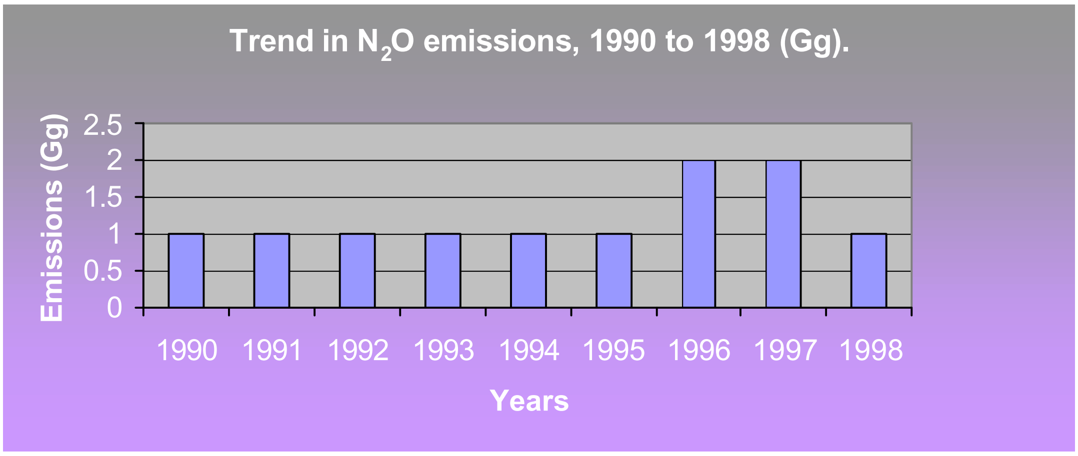
N_2O emissions

Nitrous oxide emissions in Guyana were 1Gg in the years 1990,1991, 1992, 1993, 1994, 1995, and 1998. Emissions for the years 1996 and 1997 were 2 Gg.

The identified sources for this GHG are from agricultural activities (synthetic fertilizers usage; field burning of crop residues) and waste (human sewage). Organic amendments to soil are done on a very small scale and this is particularly related to kitchen gardens. Thus emissions are insignificant.

Figure 4.9 shows trend in N_2O emissions (Gg), 1990 to 1998.

Figure 4.9: Trend in N_2O emissions, 1990-1998 (Gg).



Emissions of other indirect Greenhouse Gases
- NMVOC, CO, NO_x

The source of NMVOC in Guyana is mainly from industrial processes: food and beverages production and road paving with asphalt. Carbon monoxide (CO) and nitrogen oxides (NO_x) are emitted from field burning of agricultural residue, fuel combustion (biomass & fossil fuel) and forest/grassland conversion.

Table 4.18 and Figure 4.10 provide emissions estimates (Gg) for these gases between 1990 and 1998.

The unusual increase of NMVOC emissions in 1994 was a result of emissions from road paving with asphalt, while emissions for the other years were not estimated (data not available). Emissions gradually increase over the years from **the other sources (i.e. production of alcoholic beverages and food items),** which arose from increased productions of these items.

CO shows a gradual increase from 1990 (136 Gg) to 1993 (161 Gg), but there was a jump to (208 Gg) in 1994. Emissions gradually increased from 1994 (208 Gg) to 1997 (216 Gg), then slightly dropped to 214 Gg in 1998.

NO_x was more or less constant between 1990 and 1993, then increased suddenly to 17 Gg in 1994 and remained at that value up to 1998.

Generally, it can be seen from figure 4.10 that there was a sharp increase in emissions for these gases in the year 1994, then gradually increasing to the year 1998. The main reason for the sharp increases in the year 1994 towards 1998 was because no emissions were estimated for the period 1990 –1993 from a few sources since no data was available. Full details are given below for the increase:

NOTE: The unusual increase of NMVOC in the year 1994 is explained above.

1. **Emissions of non- CO_2 gases from the combustion of fossil and biomass fuels for the period 1990-1993 were not estimated since the relevant data was not available.**
2. **Increased crop cultivation as a result of increased cropland prior to and in the year, 1994 (mainly for rice production) generated more residues in the fields, which are burnt and emit these gases in substantial amounts.**
3. **Increased number of vehicles imported into the country prior to and in the year 1994, caused increase in the use of fossil fuel in vehicles and other machines/equipment, which is responsible for emissions, to some extent, of these gases.**

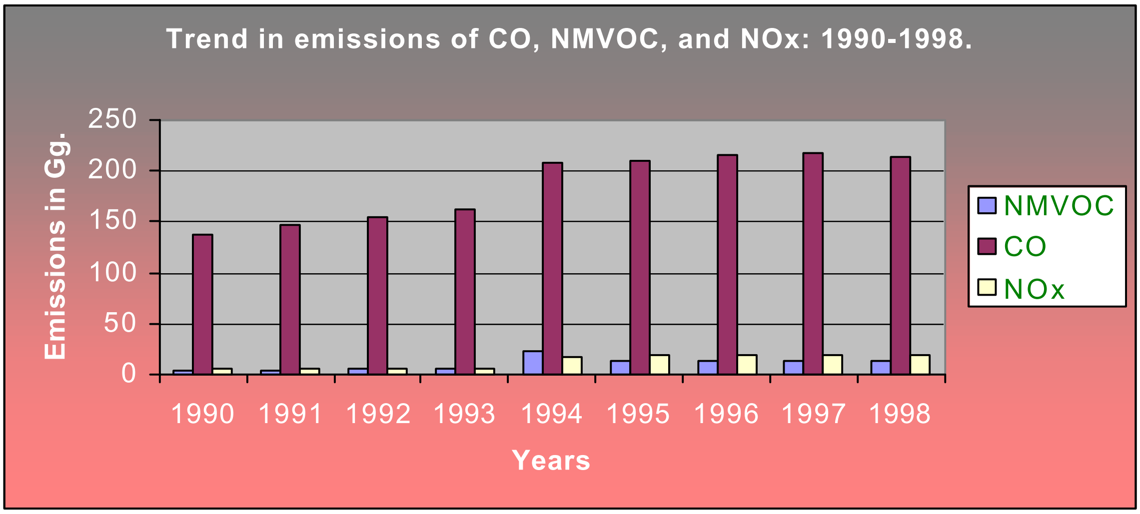
Table 4.18. Indirect GHG Emissions (Gg)

	Emissions (Gg)				
	1990	**1991**	**1992**	**1993**	**1994**
NMVOC	4	4	6	6	23
CO	136	146	155	161	208
NO_x	5	5	6	6	17

Year	**1995**	**1996**	**1997**	**1998**
NMVOC Emissions (Gg)	12	13	13	13
CO	210	215	216	214
NO_x	18	18	18	18

Note: *1. Refer to summary tables for direct sources of emissions.*
2. 1990 to 1993, emissions from fuel combustion not estimated – data not available.

Figure 4.10: Trend in emissions of the indirect greenhouse gases CO, NMVOC, and NO_x for the period 1990 to 1998.



4.9 SOURCES OF UNCERTAINTIES

It is evident that the calculations of sources and sinks of GHG's for the different sectors, as described above, incorporate several levels of uncertainty with respect to both the country activity data and the various conversion and emission factors. The ratings of these uncertainties are provided in Tables 4.B.1 to 4.B.4, which are found in appendix 4.B.

Energy Sector

The main source of uncertainty is the partitioning of the total fuels used in the different sub-sectors. This limits the results of the Sectoral Approach. However, for the Reference Approach, where the total fuels used are lumped together, there is lesser or very little uncertainty. Almost all activity data have been sourced locally from the Guyana Energy Agency.

Another source of uncertainty in the Energy Sector, regarding activity data, is with respect to the Memo items. For International Marine Bunkers, for instance, uncertainties exist since the data was partly estimated. Also, country statistics on charcoal and firewood (Biomass) burning were estimated. As for the emission factors for the various GHG's (CO_2, CH_4, N_2O, NOx, CO, NMVOC) the IPCC default values (mostly Tier 1) were used in all instances, since country–specific measurements are not available.

Industrial Sector

GHG emissions are restricted to NMVOC in the Road Paving and Alcoholic Beverages and Food Production industries. These two sources of emissions were the only ones relevant to Guyana. Activity data for these were obtained primarily from the Guyana Bureau of Statistics, so that uncertainties are minimal.

However the NMVOC emission factors are based on the IPCC default values, which may be somewhat unrepresentative based on the age and condition of the factories. Here again country specific conversion factors are not available.

Agriculture Sector

Several areas of uncertainty are encountered. FAO Statistical Yearbooks were used to obtain estimates of some animal population since national data did not address all types of livestocks. Also, data on the field burning of agricultural residues had to be derived from the IPCC methodology default values and expert estimates of the fraction of residues burnt in the field (locally) were used.

With regards to Prescribed Burning of Savannah, this is not a regular activity and may occur in small areas during the dry seasons. Actual data on savannah burnt annually were not available. However, the total area burnt annually represents a small percentage of the total savannah area. The IPCC default value (0.5) was not used. Rather, a factor of (0.065) was estimated to be relevant to Guyana. This is one area where uncertainty exists.

Land Use Change and Forestry

There are a number of uncertainties relating to GHG emissions and removals in this sector. There was a difficulty in assessing the fraction of the forested area which was anthropogenically impacted. In Guyana, selective logging is the criterion for timber extraction from an area. As such, to determine the actual area disturbed from logging operation was somewhat difficult. However, the Guyana Forestry Commission, based on it's Forestry Management Plan provided estimates. Areas being disturbed by mining activities and lands occupied/used by indigenous peoples were also estimated. There are uncertainties in the values assigned to these activities.

With regards to emission and conversion factors, the IPCC default values were used. Given the very general nature of these default values, country-specific values such as annual growth rate of forests may be quite different and introduce significant uncertainty in the GHG emissions and removals calculations.

Data on abandonment of managed lands was not available. However, initial assessment indicates that this will be insignificant. Hence, it was not considered in the inventory.

Waste Sector

The methodology utilizes population statistics for urban areas and this was used in the calculation of CH_4 emissions from solid waste disposal sites. The default values for India were used and the urban population statistics were also estimated. There is uncertainty here since the actual amount of waste deposited in disposal sites was not used since no data was available.

In the case of N_2O emissions from human sewage, the IPCC default values were used. Also, the per capita protein consumption that was used was that for the Bahamas. This may not be applicable to Guyana and is a source of uncertainty.

Furthermore, although there are both domestic and industrial sources of wastewater in Guyana, CH_4 emissions were not calculated because there is no anaerobic treatment of wastewater.

Summary

In summary, the GHG emissions and removals for Guyana for the different sectors were calculated to the best of knowledge and ability. However, it must be cautioned that there are uncertainties in these estimates where the degree of uncertainty varies within each sectors.

The capacity of Guyanese Institutions to clear up these uncertainties is not there. The expertise to deal with these issues also needs to be addressed. However, with assistance from the UNFCCC, the capacity can be improved and studies can be attempted to address the uncertainties that have been highlighted.

4.10 SUMMARY AND CONCLUSIONS

Based on the inventory of GHG for Guyana for the reference year 1994, and the years preceding and following, it is evident that insofar as **CO_2 Emissions and Removals** are concerned, Guyana can be considered as a **Net Sink Country**, namely removals (**-26,664.47 Gg**) greatly exceed emissions (**1,446 Gg**) in 1994, resulting with a removal balance of (-25, 218 Gg) for CO_2.

Furthermore, CO_2 removals, which are largely due to absorption by its vast tracts of luxuriant tropical forests, are calculated based on the relatively small (13.8 % in 1998) anthropogenically-impacted fraction of the total forest area (16,450,000 ha). Guyana can increase its CO_2 sink capacity, through consideration of its total forest area, if it can justify the fact that its policies on forest conservation and preservation, whether or not with carbon sequestration in view, is an anthropogenic act.

As shown in the inventory, CO_2 emissions derived mainly from fuel combustion activities in the Energy sector. Any mitigation effort by Guyana can therefore focus on the activities in this sector.

Non-CO_2 emissions in Guyana are relatively small. **CH_4** emissions for instance derive mainly from rice cultivation and enteric fermentation in animals and manure in the **Agriculture** sector (**40.95 Gg in 1994**). **CO**, the only other non-CO_2 gas of note is emitted by the **Energy (45 Gg)**, **Land Use Change and Forestry (68 Gg)** and the **Agriculture (95 Gg)** sectors in 1994. Guyana's mitigation efforts can therefore be directed at the activities in these sectors.

The national inventory was calculated using rough estimations due to the lack of adequate activity data, and applying indirect default emission factors. Guyana needs to develop the capacity to prepare emission factors for local conditions so that uncertainties in future inventories may be reduced.

CHAPTER FIVE

IMPACTS AND VULNERABILITY ASSESSMENT

Guyana, being a relatively large country with both a Tropical Coastal Marine Environment where most of the population and economic activity are located and an interior Continental Tropical/Equatorial Environment would be most vulnerable to climate change and impacts such as sea level rise, especially in the coastal zone, and in the water resources, agriculture, forestry, energy and health sectors.

A breach of the sea defence

5.0 IMPACTS AND VULNERABILITY ASSESSMENT

5.1 INTRODUCTION

On account of human activities related to development practices, life style and population expansion, such as rapid industrialization and land-use changes, including forest utilization, the atmospheric concentration of certain gases – carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x) and chlorofluorocarbons (CFC's) - have recently been increasing at an alarming rate. It is currently believed that, if present rates of emissions of these so-called greenhouse gases are maintained, a doubling of their combined and effective concentration could occur by around the year 2050. It is feared that an effective doubling of greenhouse gases could conceivably affect the earth's radiation and energy balances, which could eventually lead to climate change and as a consequence, sea level rise. Such a change in climate and sea level can have severe impacts on different ecosystems and on society both globally and regionally. Guyana, being a low lying state (according to Article 4.8 (b) of the Convention) and having a biodiversity consisting of numerous fragile ecosystems, can be deemed to be highly vulnerable although it is a net sink country in GHG's.

5.2 CLIMATE CHANGE AND SEA LEVEL SCENARIOS FOR GUYANA

5.2.1 Observed Climate

For this analysis, the climate record (temperature and rainfall) for the Botanical Gardens in the Capital city, Georgetown, is used. Georgetown is located at 6^0 47' North Latitude, 58^0 09' West Longitude, on the mouth of Demerara River in the Coastal Plain. Temperature data span close to 89 years (1909 to 1998) and rainfall data coverage exceeds 100 years (1884 to 1998).

5.2.1.1 Temperature

Figure 5.1 shows the yearly temperature variation with mean maximu m and minimum temperatures also included. Using linear extrapolation, the maximum temperature has shown an increase of 0.8^0C while the minimum temperature has shown an increase of 1.2 ^{0}C with a mean annual increase of 1.0 ^{0}C over the period of record. This supports the observed indication elsewhere in the Caribbean (Singh, 1997), that a greater increase in nighttime temperatures has been contributing to the observed global warming. This observed trend also corresponds to a decrease in the diurnal temperature range of about 0.5 ^{0}C - see Figure 5.2. Both the relatively greater increase in the night-time minimum temperature and the decreasing diurnal temperature range are symptomatic of global warming which is being demonstrated by increases in the night-time temperatures (Singh, 1997).

Seasonal temperatures are modulated by the rainfall amounts during the seasons. Hence, there is not expected to be significant fluctuations in the seasonal temperature records.

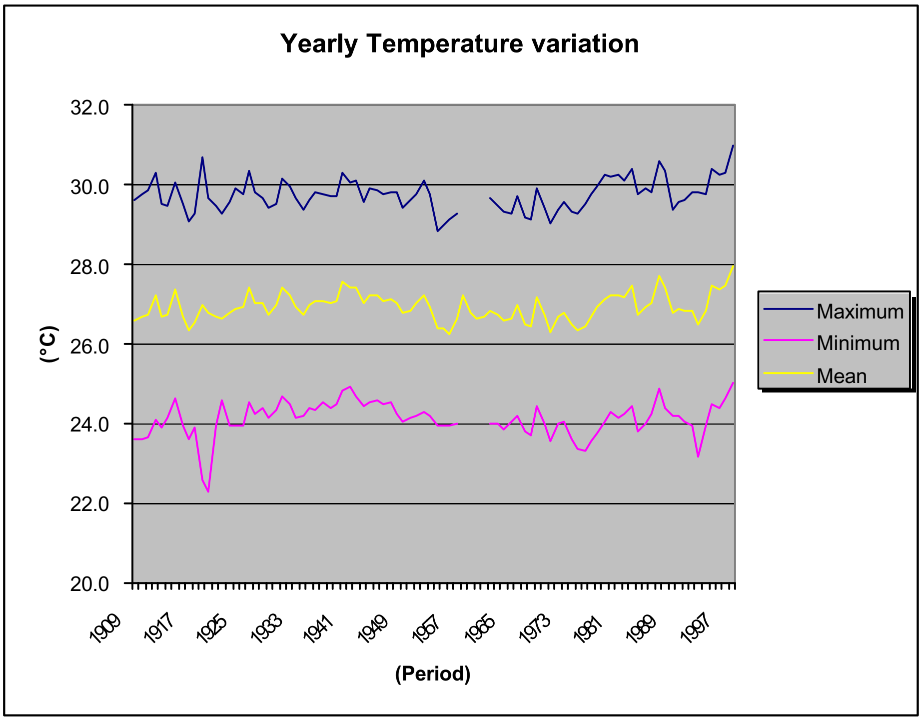


Figure 5.1: Yearly Temperature Variation at Botanical Gardens,

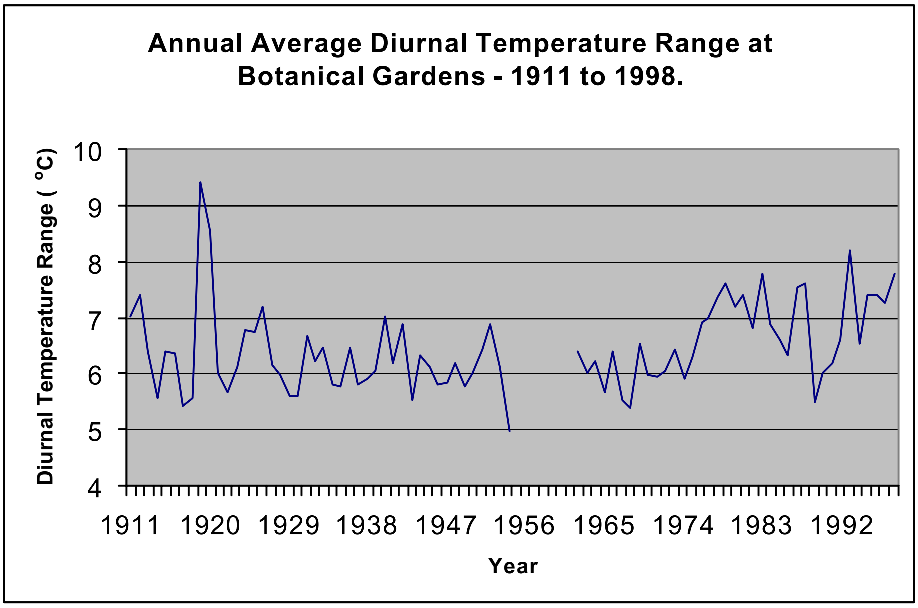


Figure 5.2: Annual Average Diurnal Temperature Range at Botanical Gardens – 1911 to 1998

When Georgetown Botanical Gardens mean air temperature (Figure 5.3) is compared to Global Average Temperatures (Figure 5.4), then there are some similarities:

- Temperatures have been rising from about 1890 up to about 1940,
- Then there was a decrease until the late 1970s, when temperatures increased again,
- The highest average temperatures were recorded in the 1980s and 1990s. However, there was a short period about 1940 when comparable high average temperatures were recorded.
- The highest average temperature was recorded in 1998.

The annual air temperatures at Georgetown Botanical Gardens also showed a pattern of responding to the cooling effect of major volcanic eruptions around the world - see Figure 5.3. The last cooling period during the early 1990s correlated with the Pinatubo eruption. It is therefore a consideration that the increase in air temperature in Guyana is being significantly masked by the cooling effect of the abundant aerosols introduced into the atmosphere during volcanic eruptions.

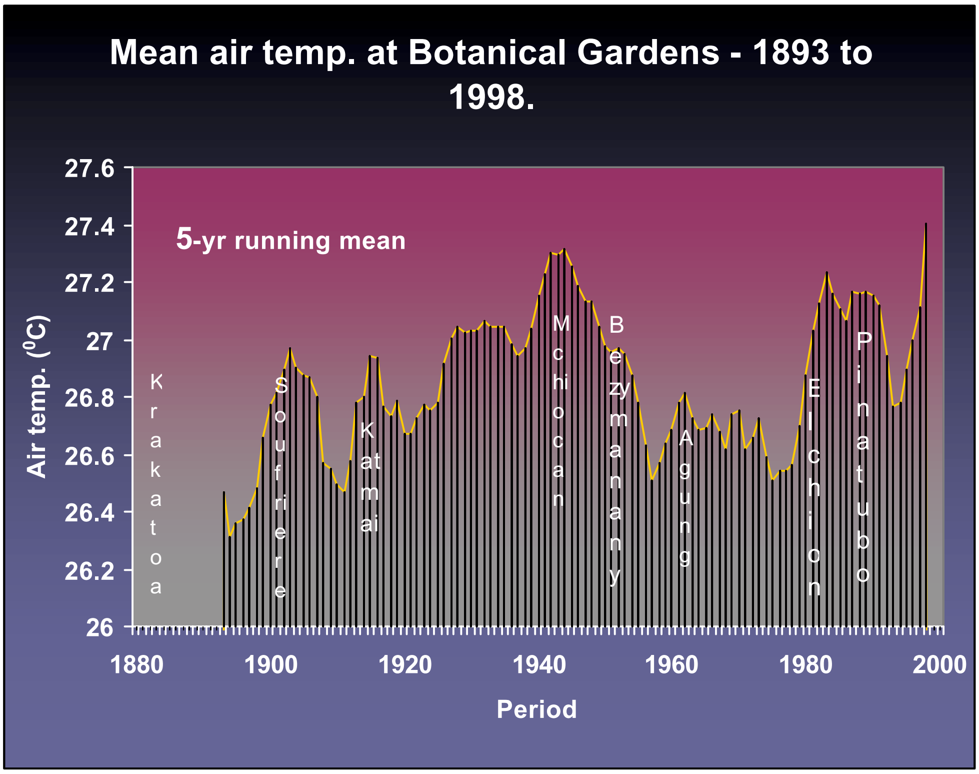


Figure 5.3: Annual Surface Temperature Variation, Botanical Gardens, Georgetown

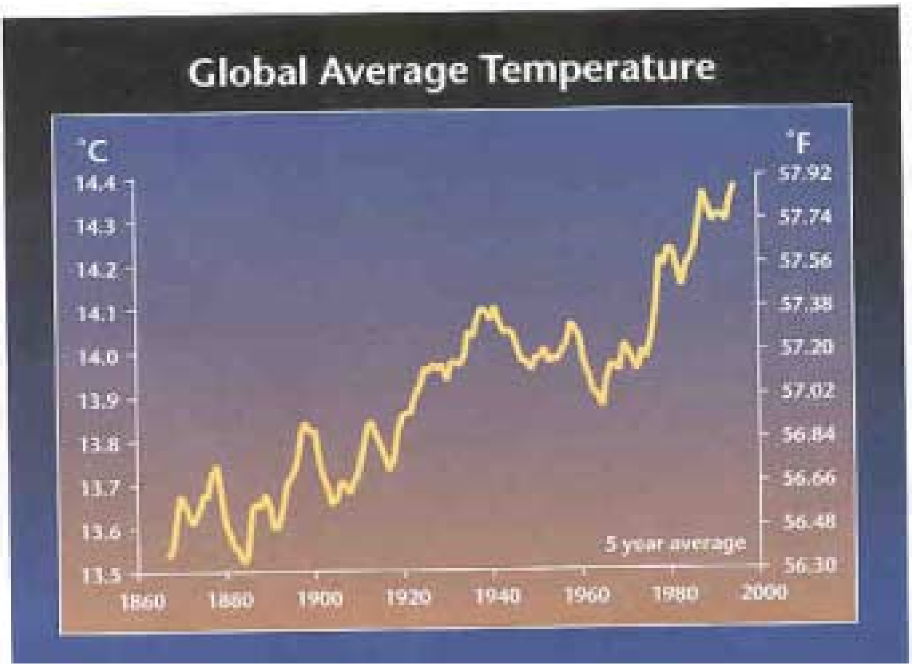


Figure 5.4: Average Global Surface Temperature Variation (reproduced from a WMO Publication)

5.2.1.2 Rainfall

Figure 5.5 shows the five-year running mean anomalies of annual rainfall amounts from the international normal (1961-1990) for Georgetown Botanical Gardens. Prior to 1960, annual rainfall amounts were generally above or about normal. However, from 1960 and onwards, there has been more below-normal periods than above-normal periods.

While ENSO events have been shown to be affecting Guyana (Simon, 1997) there seems to be a mechanism which is resulting in decreasing annual rainfall amounts during the last two decades (see Figure 5.5) when surface air temperature has been increasing. It appears that increased evaporation due to higher surface air temperatures did not result in higher rainfall. It could very well be that cloud cover has increased but this was due to more stratiform cloudiness rather than connective cloudiness. However, within the 1990s it has become apparent that convective storms have become more intense but fewer. The result was high intensity rainstorms leading to short-period flooding. The clusters in the Intertropical Convergence Zone off the Guianas are smaller and fewer but more intense. The monthly rainfall is therefore being accounted for by fewer days with higher rainfall.

With regards regional climate events, the ENSO has been very pronounced especially in the 1990s. While the EL NIÑO of 1982-3 did have an impact on Guyana's rainfall, the effect was not sufficiently intense to cause concerns for agriculture, etc.

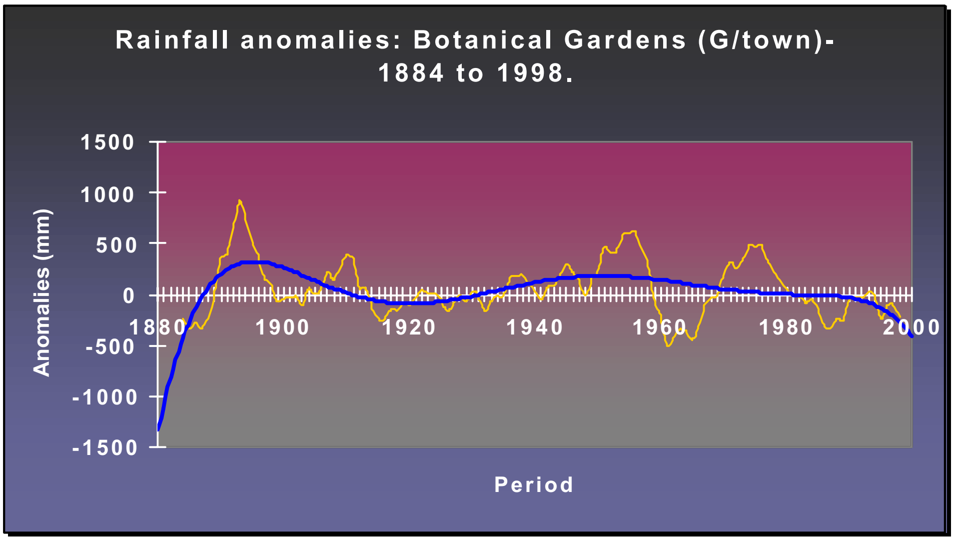


Figure 5.5: Anomalies of Annual Rainfall from the normal for 1961 – 1990 in mm, Botanical Gardens

However, the 1997/1998 El Niño event produced widespread drought with accompanying forest fires and a significant impact on the economy of the country. The La Niña of 1996 caused severe flooding to affect several parts of the country. In 1999 and 2000, La Niña's influence can be blamed for sporadic flooding especially of coastal regions.

The questions are:

- Will rainfall continue to have larger year to year variability as temperatures increase?
- Will rainstorms become more intense as global warming continues?
- Will ENSO events intensify as a consequence of global warming?
- Will doubling/tripling of the concentration of greenhouse gases in the atmosphere increase/decrease rainfall amounts in the rainy seasons?
- Will the rainy seasons shift, extend, or shorten as a consequence of global warming?

These questions may be answered but significant monitoring of climate and research will have to be done. These are needs which will have to be addressed in accordance with Article 5 of the Convention.

5.2.2 Scenarios of Future Climate Change

There are now discernable evidences that increases in atmospheric concentrations of greenhouse gases due to anthropogenic activities would warm the earth's atmospheric system (IPCC, 1996). In order to assess the effects of future climate change and to take appropriate adaptation measures against any adverse effects, estimates of how fast and to what extent global warming will occur are necessary. The most convenient and expeditious method has been the generation of future climate change and sea level rise scenarios using the A-O GCM (Atmosphere-Ocean General Circulation Model) approach.

5.0 IMPACTS AND VULNERABILITY ASSESSMENT

Recent A-O GCMs adequately couple the atmospheric and oceanic circulations and in some cases emission scenarios of future greenhouse gases, tropospheric aerosols and, assumptions on population and economic growth, energy availability and fuel mix, are considered (IPCC, 1992). The climate simulations derived from these A-O GCM's have been extensively used in the development of scenarios of regional climate change for impacts assessment.

5.2.2.1 CGCM 1

In this chapter, we use the results generated by the most recent A-O GCM of the Canadian Climate Centre (CGCM 1) run in transient mode with CO_2 increasing by the observed values to the present and then by 1% per year into the future, to create regional climate change scenarios for the region in and around Guyana (see Figure 5.6). Cells 2, 3, 5, 6, 8, 9 and 11 include the major part of the territorial area of Guyana. For each of the grid cells, climatological data for 3 time slices: 1975 – 1995 (present), 2020 – 2040 (2 x CO_2) and 2080 – 2100 (3 x CO_2) are selected. For each of these time periods, changes in near-surface rainfall (Table 5.1), temperature (Table 5.2), evaporation (Table 5.3) and water deficit (Table 5.4), as simulated by CGCM 1 are extracted in monthly groupings corresponding to the First Dry Season (FDS: February to April), the First Wet Season (FWS : May to July), the Second Dry Season (SDS : August to October) and the Second Wet Season (SWS : November to January) of Guyana.

Figure 5.6: Selected Grid Cells in and around Guyana for CGCM 1

5.0 IMPACTS AND VULNERABILITY ASSESSMENT

Table 5.1: THE CANADIAN A-O GCM (CGCM 1) PROJECTIONS OF RAINFALL (mm dy^{-1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.30	-0.69	-0.31	+0.30	-0.39	-0.16	-0.14	+0.25
3	-0.96	-0.93	-0.51	-0.15	-1.36	-0.92	-0.35	-0.07
5	+0.08	-0.65	-0.68	+0.30	+0.22	-0.34	-0.80	+0.29
6	-0.41	-1.44	-1.02	+0.07	-0.79	-2.49	-1.47	-0.12
8	-0.26	+0.09	-0.38	+0.11	+0.26	-0.80	-1.63	-0.09
9	-0.17	-0.04	-0.51	-0.71	+0.08	-1.83	-2.10	-1.48
11	-.0.23	-0.26	+0.52	-0.50	-0.19	-0.59	-1.02	-1.15
AVERAGE	-0.32	-0.56	-0.41	-0.08	-0.31	-1.02	-1.07	-0.34

Table 5.2: CGCM 1 PROJECTIONS OF AIR TEMPERATURE (°C) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	+1.20	+1.04	+1.64	+1.73	+4.35	+3.99	+4.53	+4.79
3	+1.13	+1.06	+1.59	+1.77	+4.28	+3.99	+4.90	+5.08
5	+1.22	+1.17	+1.35	+1.62	+4.24	+4.06	+4.45	+4.76
6	+1.09	+1.01	+1.08	+1.20	+4.01	+3.93	+3.93	+4.00
8	+1.10	+1.12	+1.09	+1.16	+4.14	+3.99	+3.96	+4.07
9	+1.05	+1.01	+1.01	+1.02	+4.10	+3.95	+3.91	+3.88
11	+1.21	+1.05	+1.01	+1.07	+4.18	+3.84	+3.74	+3.87
AVERAGE	+1.14	+1.07	+1.25	+1.37	+4.19	+3.96	+4.20	+4.35

Table 5.3: CGCM 1 PROJECTIONS OF EVAPORATION RATE (mm dy^{-1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.17	-0.12	-0.37	-0.36	-0.22	+0.02	±0.00	-0.18
3	-0.13	± 0.00	-0.33	-0.65	-0.20	+0.11	-0.45	-0.66
5	-0.15	-0.11	-0.06	-0.38	-0.18	+0.05	+0.03	-0.37
6	+0.01	+0.02	+0.14	-0.05	+0.27	+0.28	+0.39	+0.14
8	+0.08	± 0.00	± 0.00	-0.06	+0.13	+0.16	+0.34	+0.13
9	+0.11	-0.12	+0.01	-0.04	+0.33	+0.22	+0.30	+0.28
11	+0.15	+0.10	+0.02	+0.16	+0.54	+0.55	+0.63	+0.41
AVERAGE	-0.01	-0.03	-0.08	-0.19	+0.10	+0.19	+0.18	-0.04

Table 5.4: CGCM 1 PROJECTIONS OF WATER DEFICITS (mm dy^{-1}) FOR GUYANA

	Doubling CO_2 (2020 to 2040) - (1975 to 1995)				**Tripling CO_2 (2080 to 2100) - (1975 to 1995)**			
CELL	FDS	FWS	SDS	SWS	FDS	FWS	SDS	SWS
2	-0.13	-0.58	+0.06	+0.66	-0.17	-0.18	-0.14	+0.43
3	-0.83	-0.93	-0.18	+0.49	-1.17	-1.03	+0.09	+0.59
5	+0.23	-0.54	-0.62	+0.68	+0.40	-0.39	-0.83	+0.66
6	-0.42	-1.46	-1.16	+0.12	-1.06	-2.77	-1.87	-0.26
8	-0.33	+0.09	-0.37	+0.17	+0.13	-0.96	-1.97	-0.22
9	-0.28	+0.07	-0.52	-0.68	-0.25	-2.05	-2.40	-1.76
11	-0.38	-0.36	+0.50	-0.66	-0.73	-1.14	-1.65	-1.56
AVERAGE	-0.31	-0.53	-0.33	+0.11	-0.41	-1.22	-1.25	-0.30

5.2.2.1.1 Temperature Change

For a doubling of CO_2 concentration in the atmosphere, the temperature of Guyana is expected to rise in the early part of the twenty-first century by 1.2°C on average but the Second Wet Season (SWS) is predicted to attain the highest increase of 1.4°C. Southern Guyana inclusive of the Rupununi Savannahs are expected to have the highest increase in excess of 1.5°C during the Second Dry Season (SDS) and the SWS.

For the latter part of the twenty-first century, with a tripling of the concentration of CO_2, temperature will rise by 4.2°C on average. Here again, Southern Guyana, including the Rupununi Savannahs, is expected to have the highest increases, in excess of 4.5°C during the SDS and the SWS.

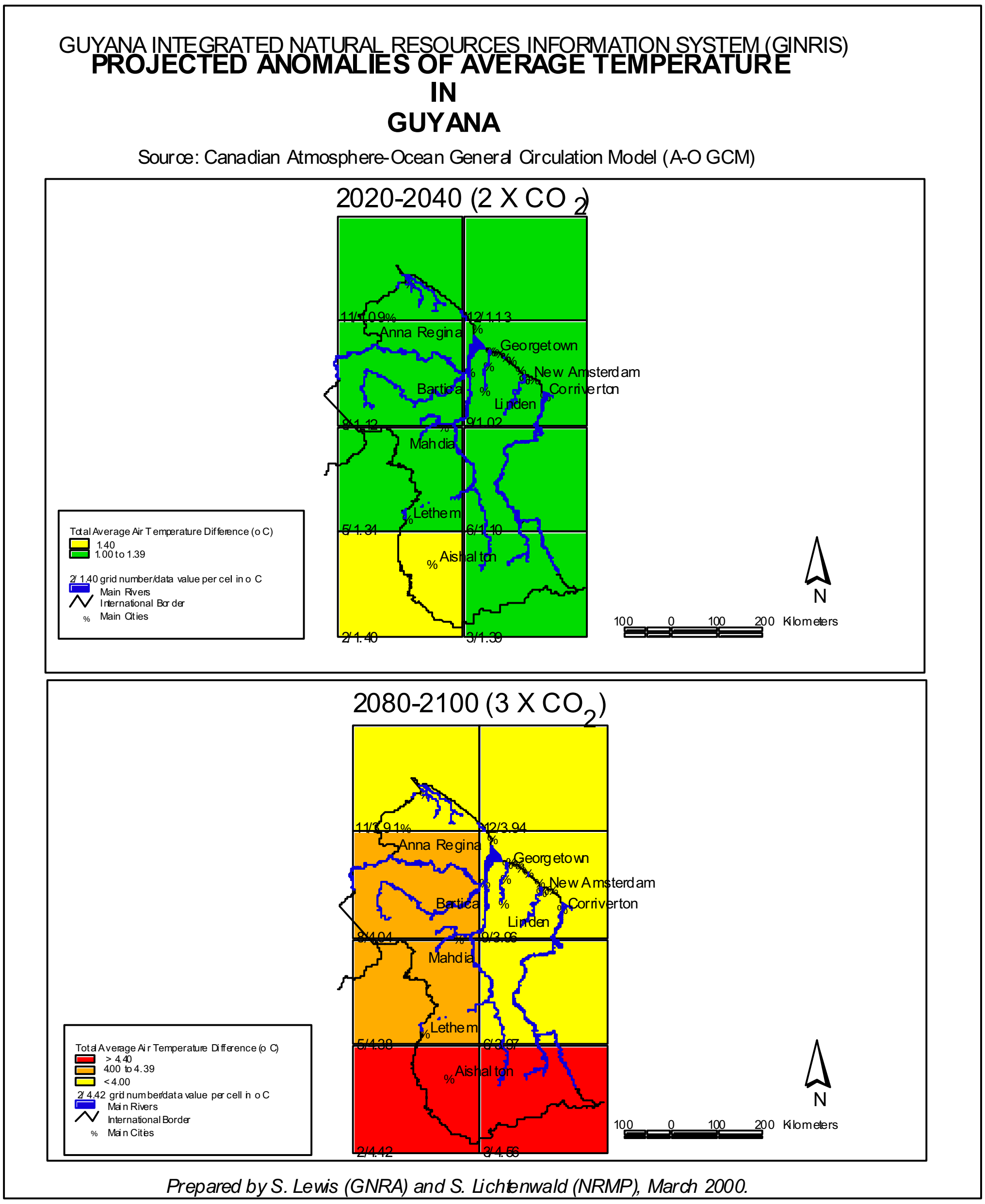


Figure 5.7: The regions of Guyana which will be affected by temperature changes due to increased CO_2 concentrations.

5.2.2.1.2 Rainfall Change

For a doubling of the concentration of CO_2, rainfall is expected to decrease by an average of 0.34 mm dy^{-1} or 10 mm per month. The decrease appears to be higher, 17 mm per month and 12 mm per month in the First Wet Season (FWS) and the SDS respectively.

For a tripling of the concentration of CO_2, the average decrease is expected to be 0.69 mm dy^{-1} or 21 mm per month. Here again, the FWS and the SDS will experience decreases higher than 1 mm dy^{-1} or 30 mm per month.

Again, Southern Guyana is targeted for the largest decreases in both the doubling CO_2 and tripling CO_2 scenarios of CO_2 concentration. However, with the tripling of CO_2 concentration, Northern Guyana (including the coast) is also expected to be affected by significant rainfall decreases.

Figure 5.8 shows the regions of Guyana which will be affected by rainfall decreases due to increased CO_2 concentrations.

5.2.2.1.3 Evaporation and Water Deficits

As for the change in evaporation rate, the slight (~ 1 ^oC) average increase in temperature, as a consequence of CO_2 doubling, does not translate into significant evaporation (less than 0.1 mm dy^{-1}). However, for a tripling of the CO_2 concentration, evaporation generally increases, in response to the higher temperature increase, to about 0.11mm dy^{-1}. The southern parts of Guyana will not be significantly affected but northern Guyana will, in general, experience increases of about 0.22 mm dy^{-1} or 7 mm per month. The northwest region will be subjected to evaporation rate increases in excess of 0.40mm dy^{-1} or 12 mm per month in all seasons.

Water deficit is defined as the difference between rainfall and evaporation. A positive value indicates that rainfall exceeds evaporation while a negative value indicates that rainfall is insufficient to meet the loss of water due to evaporation.

With a doubling CO_2 scenario, the average deficit is expected to be 0.27 mm dy^{-1} or about 8 mm per month. Southern Guyana will experience large water deficits especially in the FWS and SWS. With a tripling CO_2 scenario, the average deficit becomes 0.8 mm dy^{-1} or 24 mm per month. However, in this case it is northern Guyana which will encounter deficits in excess of 0.73 mm dy^{-1} or 22 mm per month with large deficits expected in the FWS and SDS.

A common observation, with both scenarios, is that southern Guyana is expected to have positive water deficit values in the SWS. That is, rainfall is expected to be higher than evaporation.

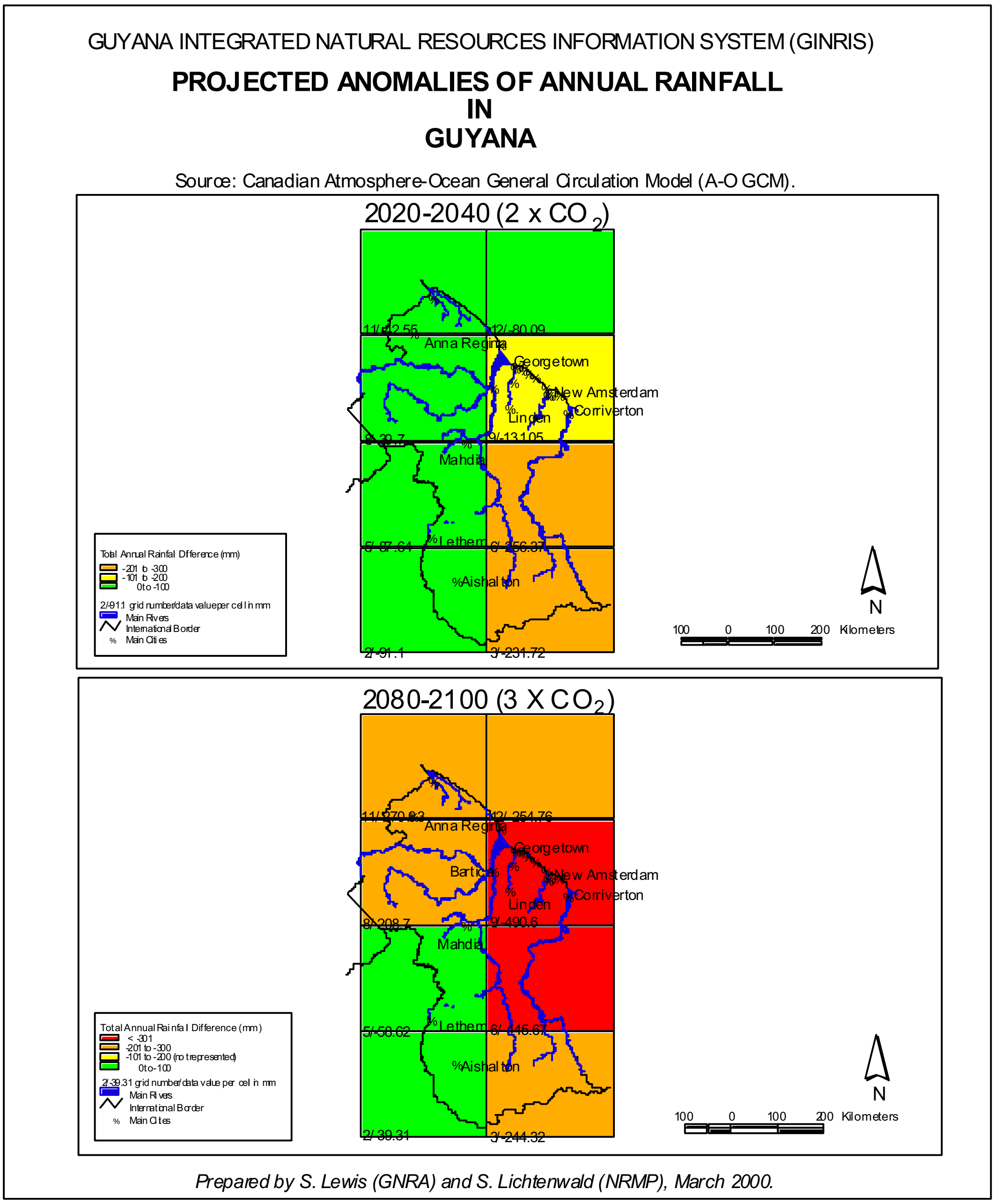


Figure 5.8: The regions of Guyana which will be affected by rainfall changes due to increased CO_2 concentrations.

5.2.2.2 Hadley Centre A-O GCM

For purposes of comparison and validation, we also use the results of the Hadley Centre A-O GCM (HadCM2Gsal) retrieved from the scenario generator SCENGEN within MAGICC (Model for the Assessment of Greenhouse gas induced Climate Change). Two future time periods centered around 2030s (2016-2045), corresponding to the 2 x CO_2 scenario and 2090s (2076-2105), corresponding to the 3 x CO_2 scenario, have been used, to generate scenarios of changes in surface air temperature and precipitation for Guyana. However, the grid spacings (5° x 5°) are slightly different (See Tables 5.5 and 5.6).

The SCENGEN version of the Hadley Centre A-O GCM projects similar changes as the Canadian Model increases in air temperature and rainfall with the increases in greenhouse gas concentration. In fact, the CGCM 1 and Had CM2 results are remarkably similar for the 2 x CO_2 scenario for air temperature and rainfall, although the latter gives the changes of rainfall as a percentage instead of mm/day.

For the 3 x CO_2 scenario however, Had CM2 gives lower temperature projections, of the order of 1.5 to 2.0°C lesser than the CGCM 1. This may be explained by the fact, that the Had CM2 projections are from MAGICC, based on patterns of change and by the fact that Had CM2 uses the IS95a sulphate scenario which is thought to be too high. However, the 3 x CO_2 rainfall scenarios are somewhat similar, although the Had CM2 projections of decreases in rainfall are more severe, especially for the FWS.

Table 5.5: The Hadley Centre A-O GCM (HadCM2) projected changes of screen air temperature (°C) for Guyana

DOUBLING CO_2 (2016/2045) - (1961/1990)						TRIPLING CO_2 (2076/2105) - (1961/1990)			
Lat.	**Lon.**	**FDS**	**FWS**	**SDS**	**SWS**	**FDS**	**FWS**	**SDS**	**SWS**
7.5	-62.5	+0.93	+1.33	+1.20	+1.23	+1.80	+1.33	+1.87	+1.90
7.5	-57.5	+0.77	+0.90	+0.97	+0.93	+3.07	+0.90	+3.37	+3.63
2.5	-62.5	+1.43	+1.63	+1.37	+1.48	+2.07	+1.63	+2.67	+2.53
2.5	-57.5	+1.37	+1.50	+1.23	+1.40	+1.90	+1.50	+2.30	+2.13
Average		1.13	1.34	1.19	1.26	2.21	1.34	2.55	2.55

Table 5.6: The Hadley Centre A-O GCM (HadCM2) projected changes of rainfall (%) for Guyana

DOUBLING CO_2 (2016/2045) - (1961/1990)						TRIPLING CO_2 (2076/2105) - (1961/1990)			
Lat.	**Lon.**	**FDS**	**FWS**	**SDS**	**SWS**	**FDS**	**FWS**	**SDS**	**SWS**
7.5	-62.5	-1.27	-14.23	-6.10	-13.53	-12.80	-38.47	-16.07	-20.57
7.5	-57.5	+2.03	-13.57	-5.03	-11.53	-5.27	-36.60	-12.23	-14.90
2.5	-62.5	+1.83	-11.80	+3.00	-6.35	+0.17	-29.77	+4.20	-11.40
2.5	-57.5	-9.50	-12.87	-4.47	-11.98	-27.57	-32.97	-13.00	-15.67
Average		-1.73	-13.12	-3.15	-10.84	-11.37	-34.45	-9.28	-15.63

5.2.2.3 Extreme High Temperature & Precipitation Events

An analysis of model-simulated daily temperature and precipitation for the present-day atmosphere and two future time slices (2050s and 2080s) suggests that the frequency of extreme temperatures during Northern Hemisphere summer season, which more or less coincides with Guyana's First Wet Season, is likely to be enhanced thereby increasing the probability of thermal stress conditions during 2050s and more so during 2080s. Similarly, there is a possibility of a lesser number of rainy days in a year, although an increase in the daily intensity of precipitation is also expected (Lal et al., 1999). This suggests an increase in the probability of occurrence of more frequent droughts as well as floods for the future.

However, one important aspect of the observed temperature change over the globe during the past century relates to its asymmetry during the day and night. Observed warming in surface air temperatures over several regions of the globe has been reported to be associated with increases in minimum temperatures, accompanied by increasing cloudiness, and decrease in diurnal temperature range.

Any future changes in the diurnal temperature range (DTR) are important in respect of its crucial role in agriculture. GCM simulations, with increasing concentrations of GHGs in the atmosphere, suggest relatively more pronounced increases in minimum temperature than in maximum temperature over the North Atlantic and Caribbean regions on an annual mean basis as well as during Northern Hemisphere winter for both 2050s and 2080s, hence a marginal decrease of 0.3°C to 0.7°C in diurnal temperature range.

5.2.2.4 ENSO and Precipitation Variability

In general, Guyana suffers acute droughts during El Niño phase and oppositely, heavy rainfall accompanied by flooding during La Niña phase. In recent years, warm episodes (El Niño) have been relatively more frequent or persistent than the opposite phase (La Niña). The ENSO phenomenon is the primary mode of climate variability on the 2 -5 year time scale. At present the weight of evidence from both observations and A-O GCM projections is that it is uncertain whether there will be any significant change to the amplitude or frequency of ENSO in the future. Thus, the current large inter-annual variability in the rainfall associated with ENSO is likely to dominate over any effects attributable to global warming. However, the frequency and increased intensity of ENSO–related effects in Guyana will need to be examined.

5.2.2.5 Tropical Cyclones

Guyana, in close proximity to the equator, has not in the past suffered significant ill effects of hurricanes. On account of its equatorial location, climate change will very unlikely change this condition, except for the increased effects of sea swells and tidal surges, in the event of major shifts in hurricane numbers, patterns and intensities in the North Atlantic and Caribbean Sea to the north of Guyana.

There is no consensus regarding the behaviour of tropical cyclones in a warmer world. However, recent studies indicate a possible increase of about 10 to 20% in intensity of tropical cyclones under enhanced CO_2 conditions. Studies also suggest that, during ENSO events, tropical cyclones and hurricanes are likely to be more severe (Jones et al.,1999; Tonkin et al., 1997; Holland, 1997). However, another study found no significant change in hurricane frequency or geographical extent for the North Atlantic under a 2 x CO_2 Climate (Royer et al., 1998). The concern for Guyana is the possibility of spiral bands of the hurricanes that pass to the north, affecting Guyana with more frequency than in the past.

5.2.3 Sea Level Rise

5.2.3.1 Past Sea Level Rise

While the severity of the threat will vary regionally, sea level rise of the magnitude currently projected by A-O GCMs (i.e. 5 mm yr^{-1}), with a range of (2-9 mm yr^{-1}), is expected to have disproportionately great effects on the economic and social development of many small island states and coastal low-lying land masses such as Guyana.

Real or eustatic sea level rise as would be driven by climate change has to be combined with relative sea level rise as caused by land displacements in the vertical. In some locations, current sea-level change is dominated by land movement of various kinds: local tectonic movements, isostatic rebound or local anthropogenic effects. These processes are not related to current climate change. By selection and correction of tide gauges, these processes are excluded from the assessment of global average ecstatic sea-level change, which is estimated to lie in the range 1.0-2.5 mm^{yr-1} averaged over the last hundred years (Church and Gregory, 2000). The primary source of information on secular trends in global sea level during the past century is the tide gauge data set of the Permanent Service for Mean Sea Level (PSMSL). Estimates of global average sea level rise using this data set fluctuate over a wide range varying from 1.0 to 2.4 mm^{yr-1} (Douglas, 1995; Smith et al 1999).

The sum of these processes indicates that between a third and a half of the 20th century eustatic sea level rise is due to thermal expansion. Thermal expansion and changes in air/sea momentum, heat and freshwater fluxes associated with climate change will alter the ocean circulation and the pattern of sea-surface height. These processes are therefore expected to have a geographically non-uniform signal in sea level change (Church and Gregory, 2000). However, Singh (1997), reported rates of mean relative sea level of 8 to 10 mm yr^{-1} in Trinidad and Tobago, but this data set is limited by its short period (15 yrs) and lack of measurements on vertical land movements.

In the case of Guyana, based on available tide gauge data for the period 1951 to 1979 for Port Georgetown, mean relative sea level rise, using a linear extrapolation is 10.2 mm yr^{-1} – see Figure 5.9. High tide change has been calculated to be 9.7mm yr^{-1} with the low tide change being 11.1mm yr^{-1}. This rate of relative sea level rise is about 5 times the global average and close to that observed in Trinidad, albeit for a later time period. This is therefore suggestive of some mechanism other than eustatic sea level rise, such as subsidence due to water extraction, ocean floor sediment loading or plate tectonics. Plate tectonics, however, does not appear to be contributing to this problem - see Chapter 3 for a discussion on this matter. Subsidence and sediment loading may both be contributing to the high rises noted in Guyana. The high rises observed in Trinidad and in Guyana may suggest a generalized increase of sea level in the region.

This discussion did not examine the effects of the North Equatorial Counter Current, the Guyana Current and the eddies within the Guyana Current on the level of the sea off Guyana. These will definitely result in changes in water accumulation off the coast and may contribute to acute rises over short periods of time resulting in overtopping of defences and inundation of vulnerable areas, especially where weak earthen dams and mangrove defences exist. Studies will have to be done on these effects to guage the seriousness of the vulnerability.

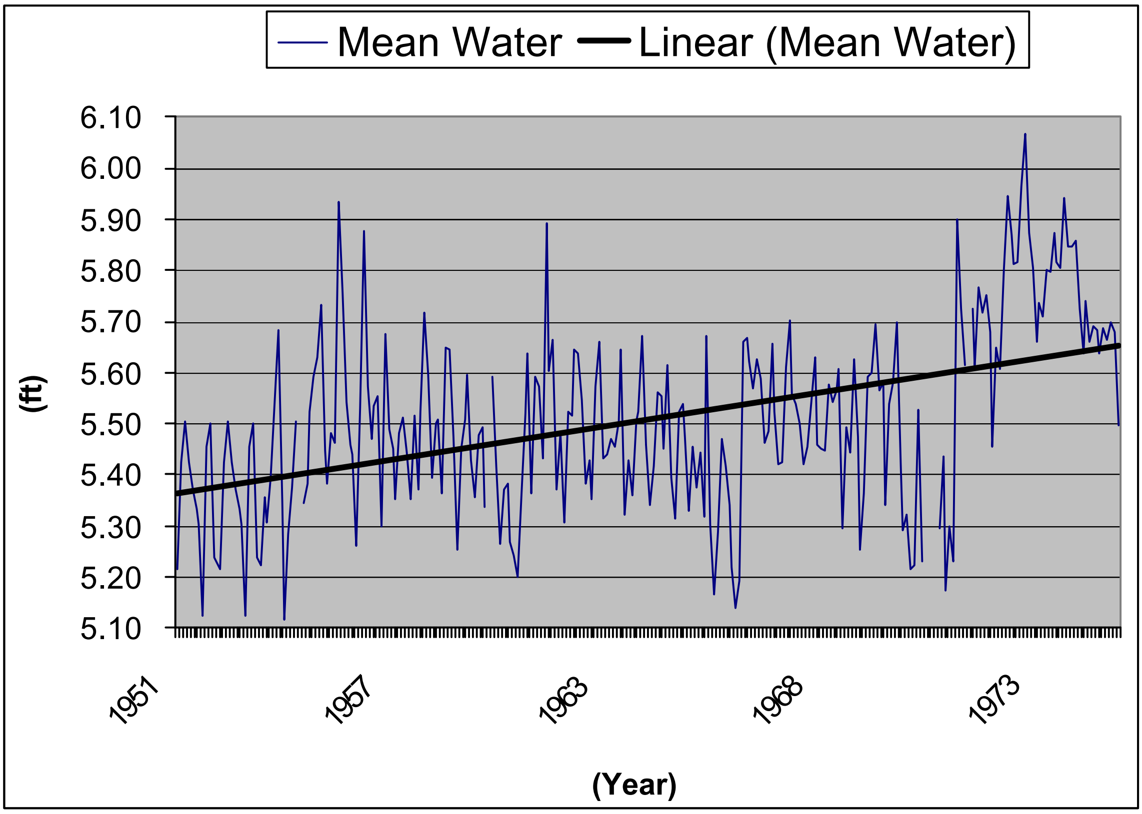


Figure 5.9: **Observed Sea Level Changes at Port Georgetown, Guyana (1951 – 1979)**

5.2.3.2 Future Sea Level Change

For the oceans, time-dependent experiments to simulate the evolution of the climate over the next century have been run with a number of AO-GCMs. Several of these have followed similar scenarios for climate forcing, starting from the beginning of this century or earlier with greenhouse gases increasing as they did historically up to 1990, then with the IS92a scenario, namely 1 % per year, for the future. Some experiments have also included the direct effect of sulphate aerosol emissions, which counteracts part of the positive greenhouse radiative forcing.

The experiments with only greenhouse gases show a range of about 0.1 to 0.2 m for the first half of the 21st century, corresponding to rates of rise of 2 to 4 mm yr^{-1}. In all the models, there is acceleration throughout the century; for the second half, the average rates are in the range 3 to 6 mm yr^{-1}.

Future sea level rise data was extracted from the CGCM 1in transient simulation, extending from 1901 to 2100, for grid cells 9 and 11 along the Atlantic coast of Guyana (see Figure 5.6 for the location of these cells).

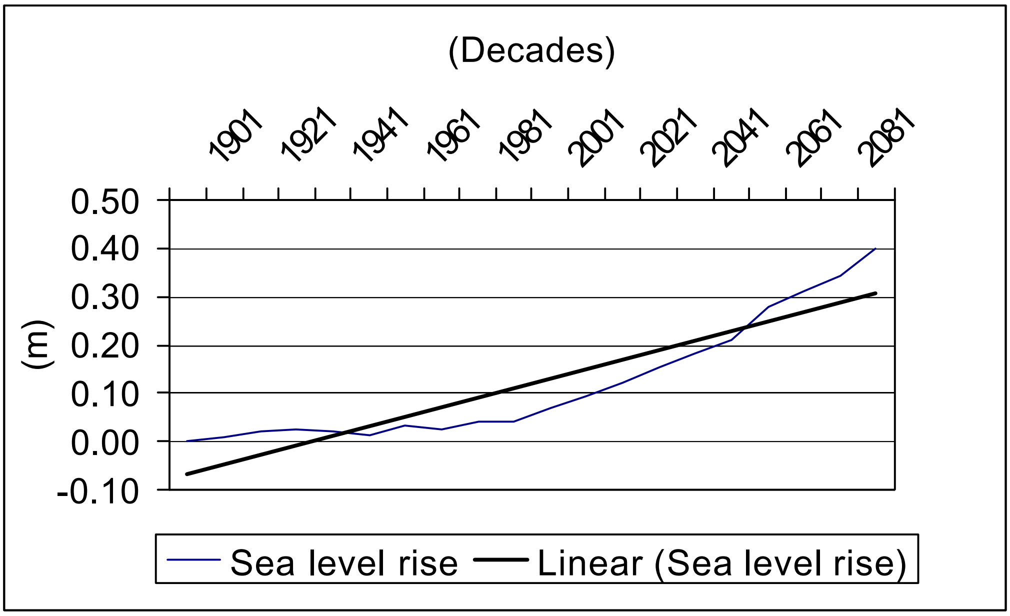


Figure 5.10: CGCM 11 Future Sea Level Projections

Figure 5.10 which is based on the steric component of mean sea level rise, that is, neglecting meltwater runoff from land areas, and on transient simulations of CGCM 1, shows that mean sea level along the Atlantic coast of Guyana is projected to rise by about 40 cm by the end of the twenty first century, that is, at a rate close to 4 mm yr^{-1}. If one were to add the contribution of meltwater from land ice, this rate of sea level rise would approach 60 cm by the end of the next century, the best guess estimate of the IPCC. Furthermore, it would appear that there is expected to be an acceleration of sea level rise at about the beginning of the 21st century. This was also a result of the other AO GCMs.

5.2.3.3 Extremes of Sea Level: Storm Surges and Waves

Changes in the highest sea levels at a given locality will result from the change in mean sea-level at that location and changes in storm-surge heights. If mean sea level rises, the present extreme levels will be attained more frequently, all else being equal. This effect can be estimated from a knowledge of the present-day frequency of occurrence of extremes of various levels (Flather and Khander, 1993; Lowe and Gregory, 2000). The increase in maximum heights will be equal to the change in the mean, and this may imply a significant increase in areas threatened with inundation (Hubbert and McInnes, 1999).

Changes in storm-surge heights would result from alterations to the occurrence of strong winds and low pressures. At low-latitude locations, such as the Tropical (North) Atlantic and the Caribbean Sea, tropical hurricanes are the major but not the only cause of storm surges. Changes in frequency and intensity of tropical storms could result from alterations to sea surface temperature, large-scale atmospheric circulation and the characteristics of ENSO (Pittock et al., 1996). Prediction of such changes is at present rather uncertain. Some recent climate model experiments have predicted a decline in tropical cyclone frequency, but no consensus has yet emerged (Royer et al., 1998; Jones et al., 1999).

Guyana’s coast is presently subjected to seawater overtopping the sea defence when high tide prevails. Noting that it is water accumulation which results in higher water levels off Guyana’s coast, it is necessary to understand how changes in the Northeast Counter Current, the eddies in the Guyana Current and the outflow of the Amazon and the other larger rivers along the Guianas affect the divergence of seawater off the Guianas and into the Caribbean Sea. It is also necessary to understand how climate change may affect the circulation of the Tropical Atlantic Ocean.

5.3 CLIMATE CHANGE IMPACTS

5.3.1 Impacts on Hydrology and Water Resources

According to most experts (IPCC, 1995), anthropogenic climate change is expected to accelerate the hydrological cycle. The resulting increase in average global precipitation and evaporation from a doubled CO_2 climate is estimated at between 7 and 15%. However, because climate models do not agree even on the direction of change in monthly or annual precipitation, for many regions, the potential impacts on regional hydrology and water resources is highly uncertain.

The impact of climate change on water supply is also uncertain. GCM's indicate possible changes in average annual precipitation for any given region on the order of plus or minus 20% of present rainfall, once the equilibrium change in climate for a CO_2 doubling is established.

For Guyana, the CGCM 1 and the Had CM2 both project lesser and more extreme rainfall conditions and increased water deficits, especially under the 3x CO_2 (2080-2100) scenario - see Tables 5.1 and 5.4.

Because runoff is essentially the difference between precipitation and evaporation/evapotranspiration the impact on runoff could even be greater. Due to expected warmer temperatures, evaporation and evapotranspiration would most likely increase (see Table 5.3). If however precipitation decreases or stays more or less the same, runoff and subsequently the level of the water table would very likely decrease. Furthermore, where runoff decreases, water quality in streams and rivers would decline unless pollutant loads also decrease. Also, extreme fluctuations in river levels may occur and will thereafter affect bank and slope stability and hence lead to flood conditions.

Sea-level rise, a consequence of global warming, can also affect water supplies through increased salt-water intrusions into aquifers that interface with the ocean. Ground water is the major source of domestic and industrial water in Guyana and this would increase the vulnerability to this type of impact.

The impact on water demand is also very uncertain. This will depend on population growth by the time of the 2 X CO_2 climate and the changes in the various competing sectors. Water use in urban and suburban areas would probably increase, with increasing temperature, for drinking, and other domestic and industrial uses.

In agriculture, irrigators would tend to use more water to compensate for higher evapotranspiration (ET) rates. However, the ET response of plants to increasing CO_2 levels is not clear. In addition, changes in other climatic parameters such as cloudiness, humidity and windiness could further affect ET rates.

The relative value of water for alternative uses would likely change. Drinking and domestic uses would remain top priorities, but changes in seasonal and annual supplies might result in changes in the allocation of water and consideration of changes in reservoir capacity to flood control demands, power generation, fish habitat or consumptive uses such as irrigation.

5.3.2 Energy Sector

There are two major economic sectors that are very likely to be affected by anthropogenic climate change in Guyana. These would include increased energy demand for interior space cooling on the one hand and possibly decreased hydro-generating potential supply from some river basins, depending on how the water balance and the Net Basin Supply (NBS) of these river basins are affected.

In the first case, the use of electric energy for air conditioners will most certainly rise under a warmer climate. Cooling degree days (°C/days) are evaluated for the city of Georgetown using the threshold temperature of 25°C, above which cooling is required. Then, based on the maximum daily temperature, cooling degree days are calculated for the current (1975 – 1995), 2 x CO_2 (2020 – 2040) and 3 x CO_2 (2080 – 2100) climate scenarios (see Table 5.7).

In Table 5.7, it is evident that energy demand for cooling requirements would increase substantially during all seasons under the two future climate change scenarios. For instance, under the 2 x CO_2 scenario (2020-2040), cooling degree days are projected to increase by 16.9 % in the SDS to 30.0 % in the SWS, with an annual average of 23.1 %. The situation gets worse under the 3 x CO_2 scenario (2080-2100), when cooling requirements are projected to increase by 65.0 % in the SDS to 102.5 % in the FDS, with an annual average of 85.9 %, relative to 1975 – 1995.

In both cases, especially for the 3 x CO_2 scenario, energy demands for interior space cooling (commercial, residential and vehicular) are expected to increase substantially, when the temperature impact of global warming becomes a reality.

Table 5.7: Changes in cooling degree days under climate change scenarios for Georgetown, Guyana

Season	1975-95 Min Temp (^oC)	1975-95 Max Temp (^oC)	1975-95 Cooling Degree Days (^oC/days)	2020-40 Max Temp (^oC)	2020-40 Cooling Degree Days (^oC/days)	Change Rel. to 1975-95 (%)	2080-2100 Max Temp (^oC)	2080-2100 Cooling Degree Days (^oC/days)	Change Rel. to 1975-95 (%)
FDS	24.5	29.0	360	30.05	455	**26.4**	33.1	729	**102.5**
FWS	24.0	29.5	405	30.51	496	**22.5**	33.5	765	**88.9**
SDS	24.5	31.0	540	32.01	631	**16.9**	34.9	891	**65.0**
SWS	24.0	29.0	360	30.2	468	**30.0**	32.9	711	**97.5**
The Year			**1665**		**2050**	**23.1**		**3096**	**85.9**

In the second runoff potential and hence the hydro-generating capacity of certain drainage basins may decrease, thereby decreasing Guyana's capacity to supply a widely available, cheaper and non-fossil fuel form of energy.

Two drainage basins that are already targeted for hydropower generation are examined. These are the relatively small Moco Moco drainage basin and the much larger Tumatumari basin, which are all to be found in grid cell 5 of figure 5.6.

Net Basin Supply (NBS: m^3/s), which represents the potential incremental seasonal or yearly discharge and hence hydro-generating potential is based on the difference between rainfall and evaporation and basin area, and can be calculated for each drainage basin for the time slices 1975-1995, 2020-2040 and 2080-2100 by using Tables 5.1 and 5.3. Figures 5.11 and 5.12 indicate the changing NBS with time for the two basins.

For the Moco Moco drainage basin, whose area is 115km2, current (1930-1975) average discharge is 0.60 m^3/s, with a range of 0.49 m^3/s for dry years and 0.73 m^3/s for wet years. However, 1975-1995 mean annual NBS is 0.027 m^3/s (Table 5.8), this being due to neglect of base flow, inter-basin flow and lag effects that are not taken into account in NBS.

Table 5.8: Changes in net Basin Supply for hydro-power generation: Moco Moco Basin

Season (months)	1975-1995			2020-2040				2080-2100			
	P mm dy-1	E mm dy-1	NBS m^3/s	P mm dy-1	E mm dy-1	NBS m^3/s	**Change %**	P mm dy-1	E mm dy-1	NBS m^3/s	**Change %**
FDS	4.26	4.03	0.31	3.96	3.86	0.13	**-138**	3.88	3.81	0.09	**-244**
FWS	4.56	3.61	1.26	3.86	3.49	0.49	**-157**	4.40	3.63	1.02	**-24**
SDS	3.42	4.19	-1.02	3.11	3.82	-0.94	**9**	3.28	4.19	-1.21	**-16**
SWS	3.50	3.88	-0.51	3.80	3.52	0.37	**238**	3.76	3.70	0.08	**538**
Mean	**3.94**	**3.92**	**0.027**	**3.68**	**3.67**	**0.013**	**-107**	**3.84**	**3.83**	**0.013**	**-108**

For the 2 x CO_2 climate scenario (2020-2040), mean annual NBS for the Moco Moco basin decreases to 0.013 m^3/s (- 107 %), with the greatest decreases in the First Dry Season (-138 %) and the First Wet Season (-157 %). However, NBS increases substantially during the Second Wet Season (238 %) (Table 5.8 and Figure 5.11).

Similarly, for the 3 x CO_2 scenario (2080-2100), mean annual NBS decreases to 0.013 m^3/s, with the greatest decrease during the First Dry Season (-244 %) (Table 5.9 and Figure 5.8). However, as in the case of the 2 x CO_2 scenario, NBS increase substantially during the Second Wet Season (538 %).

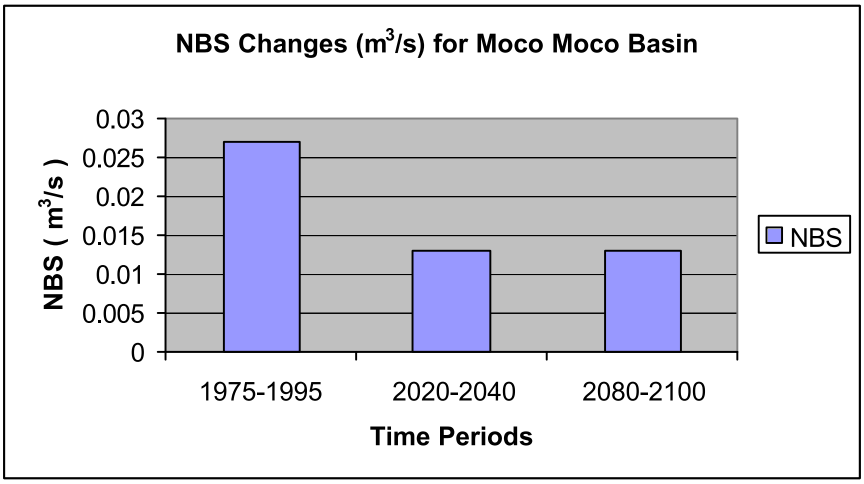


Figure 5.11: Changes in NBS for the Moco-Moco Basin for the three Climate Change Scenarios

In the case of the Tumatumari drainage basin, whose area is 3160 km^2, current (1950-1976) average discharge is 208 m^3/s. However, 1975-1995 mean annual NBS is 27.82 m^3/s (Table 5.9), this being due to the neglect of base flow, inter-basin flow and lag effects that are not taken into account in the calculation of NBS.

As for the 2 x CO_2 climate scenario (2020-2040), mean annual NBS for the Tumatumari basin decreases to 22.5 m^3/s (- 24 %), with the greatest decreases in the First Wet Season (-34 %) and the Second Dry Season (-67 %). However, NBS increases substantially during the Second Wet Season (324 %) (Table

5.9).

Similarly, for the 3 x CO_2 scenario (2080-2100), mean annual NBS decreases to 23.72 m^3/s, with the greatest decrease during the First Wet Season (-22.6 %) and the Second Dry Season (-72.8 %) - see Table 5.9 and Figure 5.12. However, as in the case of the 2 x CO_2 scenario, NBS increases substantially during the Second Wet Season (288 %) (Table 5.10).

Therefore, it would seem that NBS and hence hydro-generating potential of the Moco-Moco and Tumatumari drainage basins would generally decrease during the 2 x CO_2 (2020-2040) and 3 x CO_2 (2080-2100) climate change scenarios. Also, there are likely to be significant shifts in the seasonality of river discharge.

However, one must caution against relying totally on the data used in this analysis because the discharge data is not current and the model forecast values represent the average for a grid cell which includes rainforest and savannah types. A detailed country study will be required to assess the results of this analysis.

Table 5.9: Changes in Net Basin Supply (NBS) for hydro-power generation: Tumatumari Basin

Season	1975-1995			2020-2040				2080-2100			
	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	**Change %**	P mm dy^{-1}	E mm dy^{-1}	NBS m^3/s	**Change %**
FDS	3.44	4.00	-45.8	3.52	3.85	-27.0	**66**	3.66	3.82	-13.1	**250**
FWS	5.67	3.56	173.5	5.02	3.45	129.3	**-34**	5.33	3.61	141.5	**-22.6**
SDS	3.84	4.16	-25.4	3.17	4.10	-76.1	**-67**	3.05	4.19	-93.3	**-72.8**
SWS	2.89	3.77	-72.9	3.19	3.39	-17.2	**324**	3.17	3.40	-18.8	**288**
Mean	**4.21**	**3.87**	**27.82**	**3.97**	**3.70**	**22.5**	**-24**	**4.05**	**3.76**	**23.72**	**-17**

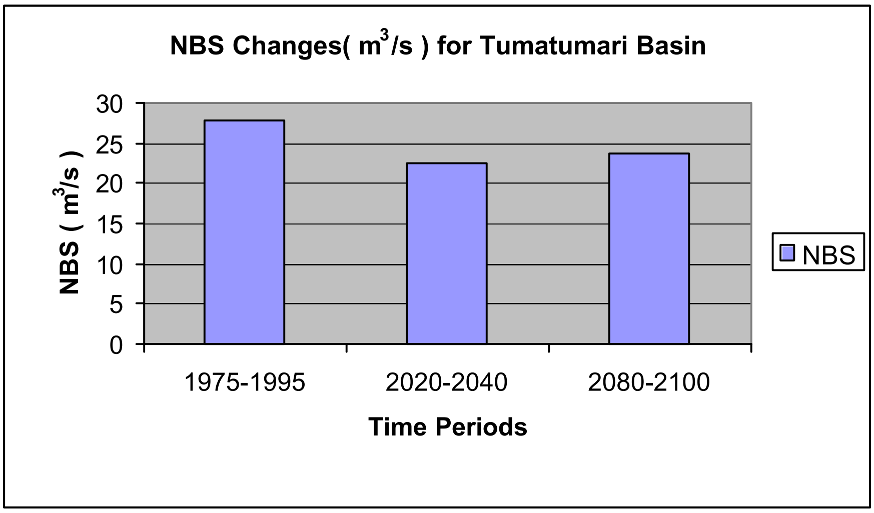


Figure 5.12: Changes in NBS for the Tumatumari Basin for the three Climate Change Scenarios.

5.3.3 Agriculture Sector

Anthropogenic Climate Change would very likely impact on agriculture, a key sector of the Guyanese economy. The agroclimatic, and possibly the soil conditions, for the growth of crops may be modified by, for example:

- Increase in drought periods and severity, and possibly wind erosion of soils , or
- More intense rainstorms leading to flooding and loss of crops, soil erosion and leaching of soil nutrients.

These would not only affect the physical constraints of crop growth and yields but also the cost of production especially when irrigation may be required to counter increased water deficits.

Two major implications of CO_2-induced temperature increase and changing climatic patterns for the growth of agricultural crops are: a lengthening of the potential growing season, and an increase in plant growth rates and thus a shortening of the required growing period. The problem of growing season length will not affect tropical countries such as Guyana. However, shortening of the growing season, through a more rapid accumulation of growing degree days, has been shown to lead to acceleration of maturation and reduced yields, especially for C3 cereal crops such as rice. In fact, in Guyana, it is rather the changes in soil moisture conditions as controlled by rainfall, rather than temperature, that may influence crop yields through excessive moisture that may cause flooding or soil moisture deficit that may restrict crop growth and yields. Should ENSO events intensify and occur more frequently, then soil moisture changes may be important.

5.3.3.1 Changes in Mean Crop Yield

In order to evaluate the vulnerability of Guyanese agriculture to anthropogenic climate change, the focus is placed on the yield changes of sugarcane and rice, two commercial crops, which significantly influence the economy of the country.

Yearly yield changes for sugarcane and rice are calculated for the 3 climate change scenarios, namely 1975-1995 (current), 2020-2040 (2 x CO_2) and 2080-2100 (3 x CO_2). Yields are calculated by coupling the most recent version (3.5) of the crop yield simulation model DSSAT (Decision Support System for Agro-technology Transfer) with climate data (daily solar radiation, maximum and minimum temperature and rainfall) from the CGCM 1 for the eastern coastal area of Guyana, namely grid cell number 9. Yield simulations are done for sugarcane over 365 days from January to December and for rice over 120 days from December to March, corresponding to the first rice crop of Guyana. In both cases, a minimum of management (fertilization, tillage) is used and no irrigation is assumed.

Sugarcane and rice yields for current climate conditions (1 x CO_2) are compared with yields under the perturbed (2 x CO_2 and 3 x CO_2) climate scenarios to evaluate the potential impacts of anthropogenic climate change on yields (Tables 5.10 and 5.11 and Figures 5.13 and 5.14).

Table 5.10: Changes in Sugarcane yields according to Climate Change Scenarios

Mean Observed Yields (kg/ha) (1979-1996)	Range of Observed Yields (kg/ha) (1979-1996)	Mean Simulated yields (kg/ha) (1975-1995)	Difference (%) Observed Simulated (1975-1995)	Mean Simulated yields (kg/ha) (2020-2040)	Range of Simulated Yields (kg/ha) (2020-2040)	**Difference (%) 2020/2040 - 1975/1995**	Mean Simulated yields (kg/ha) (2080-2100)	Range of Simulate Yields (kg/ha) (2080-2100)	**Difference (%) 2080/2100 - 1975/1995**
72,300	65,600-81,200	70,203	2.9	54,086	52,200-55,092	**-29.8**	50,739	48,764-52,753	**-38.4**

Table 5.11: Changes in Rice Yields according to Climate Change Scenarios

Mean Observed Yields (kg/ha) (1968-1997)	Range of Observed Yields (kg/ha) (1968-1997)	Mean Simulated Yields (kg/ha) (1975-1995)	Difference (%) Observed-Simulated (1975-1995)	Mean Simulated yields (kg/ha) (2020-2040)	Range of Simulated Yields (kg/ha) (2020-2040)	**Difference (%) 2020/2040 - 1975/1995**	Mean Simulated yields (kg/ha) (2080-2100)	Range of Simulate Yields (kg/ha) (2080-2100)	**Difference (%) 2080/2100 - 1975/1995**
2,920	1,530-4,000	3,180	-8.9	3,087	2,959-3,175	**-3.0**	2,744	2,639-2,840	**-15.9**

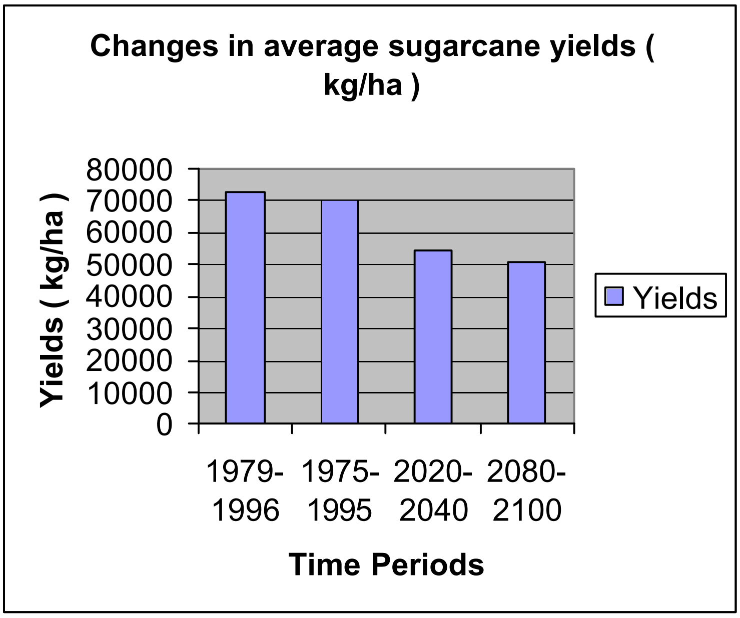


Figure 5.13: Changes in Sugarcane Yields for Guyana according to Climate Change Scenarios

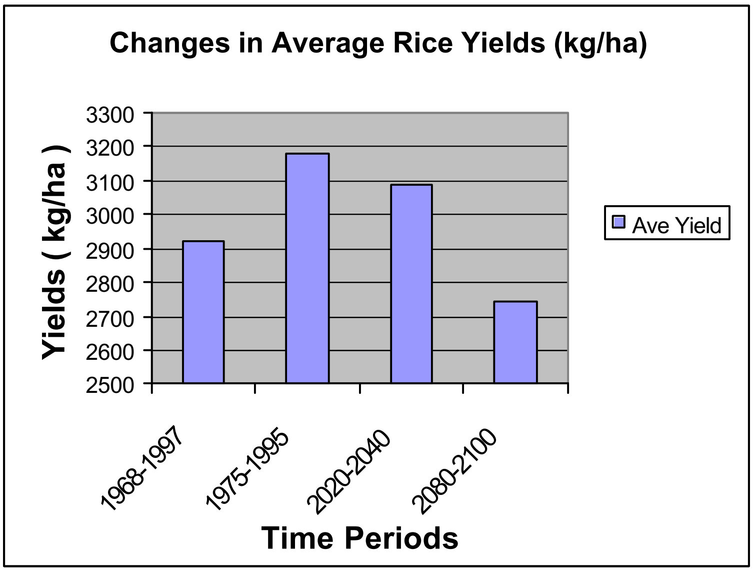


Figure 5.14: Changes in Rice Yields for Guyana according to Climate Change Scenarios

In the case of sugarcane mean observed (1979-1996) and mean simulated (1975-1995) yields for the current climate are very similar, the difference being 2.9 % (Table 5.10). Substantial yield losses are however observed for the 2 x CO_2 (2020-2040) (-29.8%) and the 3 x CO_2 (2080-2100) (-38.4 %) climate scenarios.

For rice the mean observed (1968-1997) and mean simulated (1975-1995) yields for current conditions vary by 8.9 %. However, the yield loss of 3.0 % is relatively small for the 2 x CO_2 (2020-2040) and for the 3 x CO_2 (2080-2100) climate change scenario where it rises by a factor of 5 or 15.9 %.

The yield losses for both rice and sugarcane reported above are only based on changes in climate variables, including solar radiation, maximum and minimum temperatures, rainfall and evapotranspiration rate. Decreases in yields may therefore be attributed to the increased water demand from crop transpiration and to greater respiration losses caused by markedly higher temperatures. The plant stress due to the extreme climate indicated above is not very clear and will require to be studied.

Little is currently known about changes in the inter-annual variability of temperature and precipitation, which might accompany global warming. However, in spite of the limited range of year-to-year yield fluctuations under the climate change scenarios, it is expected that future changes in climate would be accompanied by significant changes in year-to-year variability and hence by wide fluctuations in crop yields.

Furthermore, given the strongly non-linear relationship between variations in average climate and the frequency of extreme events, it is clear that climatic variations can be especially important in marginal farming areas where the risk of failure is already significant.

Changes in yield quality may also occur under a warmer climate. For instance, the decrease in the diurnal temperature range discussed earlier may decrease the sucrose content and hence the price of sugar.

One of the difficulties of estimating effects of climatic change on agriculture is that the sensitivity of yield to input such as fertilizers and pesticides also varies with climate. Also, under a warmer and possibly more humid climate projected for Guyana, the incidence of pests and disease may increase. It is evident that crop yield would be more responsive to altered fertilizer inputs during anomalous climatic periods if the mean level of nitrogen fertilization was lower than at present. This means that the adjusting of levels of fertilization can be an effective stabilizing response in extreme years. The gains in productivity however, can be eroded by significant increases in input costs and/or environmental impact (such as continued deterioration in water quality) emanating from use of agrochemicals.

Spatial shifts in comparative advantage, both regionally and globally, may occur in agriculture following anthropogenic climate change. Different crops growing in the same region often respond differently to a given change of climate. In order to optimize agricultural output in Guyana, then there might therefore be a need for a substantial switch of crops or species of crops. Likewise, the same crop grown in different regions may respond differently to a similar change of climate. The combination of these two complexities of response (by different crops or varieties in the same region and by the same crops or varieties in different regions) would bring about substantial shifts in the comparative advantage which one crop or mix of crops would have over another.

A consequence of the factors described above, together with many other sources of spatial complexity, is that climatic change can be expected to bring about a spatial shift of crop potential. Areas which are, under present climatic conditions, judged to be most suited to a given crop or combination of crops or to a specified level of management will change location. In this simplest form, this kind of shift can be seen as a shift in limits of the cultivable area.

There are also higher order impacts of climate change on agriculture, including farm profitability, farm level adjustments in terms of inputs and technology and economic and social government policy, including food security.

Assuming for the present that there is no change in costs of inputs, we can estimate the effect of yield changes on farm profitability by analyzing the effect on net returns per km^2. Changes in government agricultural support and subsidies, within the constraints of the World Trade Organization, as an appropriate response mechanism, are also to be considered.

Changes in farm profitability can be expected to affect non-agricultural sectors of the Guyanese economy. Changes in agricultural production and profitability and the effects of these on the wider Guyanese economy are likely, and in addition, may affect the level of employment.

The focus of this section is on the responses to anthropogenic climatic change of a single economic sector, agriculture. The mainly biophysical and economic effects that have been discussed above assumed no changes in technology, management or in background economic conditions (product prices, labour supply, etc.). This assumption is unrealistic, at least with respect to long-term changes in climate, because experience tells us that these factors are likely to change substantially over the kind of time-scale estimated for atmospheric $C0_2$, doubling or tripling.

The estimates are not, therefore, a prediction of future effects but a sensitivity analysis of present-day agriculture, enabling identification of those aspects and areas which may be especially vulnerable to climatic variations. This form of analysis also provides a basis for the next step: the evaluation, firstly, of potential adjustments at the farm level and, secondly, of potential policy responses at the regional and national level.

5.3.4 Forestry Sector

In the Forestry sector, non-climate change anthropogenic activities can lead to a vulnerable situation. Guyana's forests can be vulnerable to deforestation by these activities. Many different factors can be involved and their combination, relative importance, and interactions will vary not only from region to region, but also over the course of time, influenced by economic, political and social development. Frequently these activities are treated as causes that directly and obviously contribute to degrading or destroying the forestland and which strictly speaking should therefore be regarded as types or manifestations of forest destruction. These include:

- Small-scale shifting cultivation for food production, predominantly to meet the farmers' own needs (subsistence farming).
- Agroindustrial land use for production for certain cash crops for export and products from plantation crops (coffee, sugarcane, rice and palm oil).
- Extensive livestock production (cattle ranching).
- Fuelwood collection.
- Felling of trees for timber (logging).
- Clearing of forestland to exploit energy and mineral resources (mining, construction of dams and reservoirs) with installation of the required infracstructure.

The potential impacts of a CO_2-induced climate change on forestry, will be very similar to those for agriculture.

Depending upon changes in the thermal (temperature) and moisture (rainfall, evapotranspiration) regimes, forest growth rates can be expected to change. Of course, one would also have to consider how the increased CO_2 fertilization will impact upon forest growth.

Changes in the eco-climate may also trigger shifts in forest species. For instance if warmer, wetter and more humid conditions are projected, species that are currently abundant in Central Amazonia, say, may move into regions like Guyana. However, climate variability and change in seasonality will also have to be considered. For instance, if droughtier conditions occur in the dry season, this may impose severe constraints on forest growth and may be critical in determining species response.

Other factors such as soil suitability, wind changes (fertilisation) and the presence of insects and pathogens will also play a major role in forest response to climate change.

Finally the economics of the lumber industry may also change depending upon species selection, growth rates, workability (depending upon climate), government land use policies (afforestation or deforestation) and world markets.

In order to evaluate the response and vulnerability of the forest sector to climate change, the Holdridge forest classification system is used. The Holdridge system, which has been tested and applied worldwide, essentially determines the spatial distributions of the broad eco-zones, based on Mean Annual Air Temperature (MAAT: ^{o}C), adjusted for elevation where necessary, Mean Total Annual Precipitation (MTAP: mm) and the Potential Evapotranspiration Ratio (PER).

In Table 5.12, the spatial distribution of the major Holdridge eco-zones and the corresponding predominant Guyanese forest types are presented for the various grid cells shown in Figure 5.6 for the current (1975-1995) climate scenario. The present forest distribution is reflected in Figure 5.15.

It is evident that apart from differences in nomenclature, for instance Moist Tropical Forest (Holdridge) as opposed to Tall Evergreen Forest (Guyanese), the Holdridge system crudely captures the spatial distribution of the major forest species of Guyana.

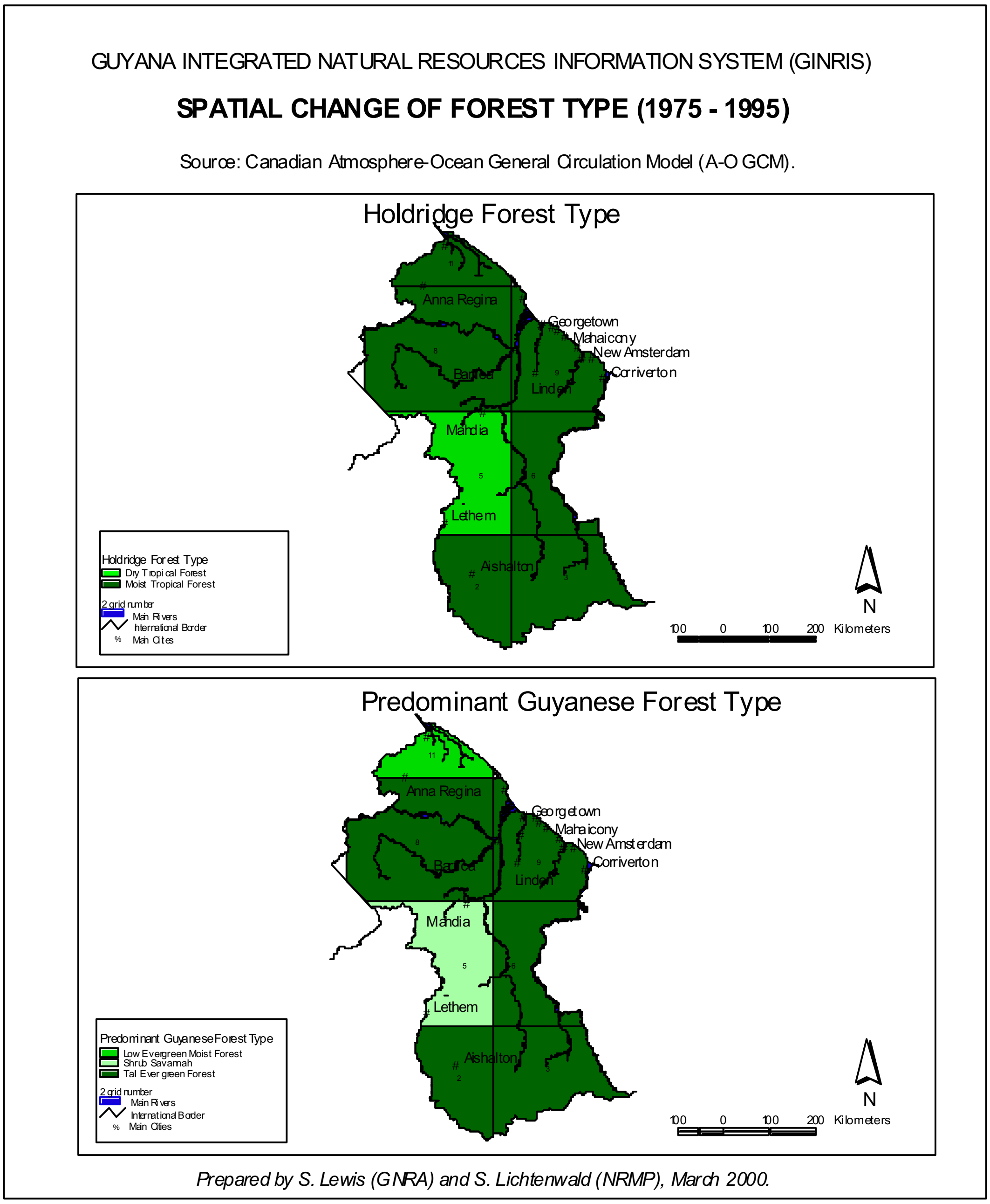


Figure 5.15: Present Forest Distribution (Holdridge and Predominant Guyanese Forest Types)

Under the 2 x CO_2 climate scenario (2020-2040), it would appear that the area of Dry Tropical Forest (Shrub Savannah) would extend at the expense of Moist Tropical Forest (Tall Evergreen Forest) in grid cells 3 and 4 (Table 13).

Furthermore, under the 3 x CO_2 (2080-2100) climate scenario, the area of Dry Tropical Forest (Shrub Savannah) would spread further, replacing Moist Tropical Forest (Tall Evergreen Forest) in grid cells 2 and 15, in addition to grid cells 3 and 4 (Table 14).

It would appear then that climate change, as shown in Tables 13 and 14, may affect the spatial distribution of the major forest zones of Guyana, with Dry tropical Forest (Shrub Savannah) replacing Moist Tropical Forest (Tall Evergreen Forest) in the southernmost (grid cells 2,3and 4) and northernmost (grid cell 15) parts of Guyana. This may have important economic consequences on the Guyanese forest industry.

Table 5.12: Holdridge Classification of Guyanese Forests for the 1975 – 1995 Climate Scenario.

	HOLDRIDGE FOREST CLASSIFICATION 1975 - 1995				
Grid cell	**MAAT (°C)**	**MTAP (mm)**	**PER**	**HOLDRIDGE FOREST TYPE**	**Predominant Guyanese Forest Type**
2	23.42	1436	0.96	Moist Tropical	Tall Evergreen
3	25.12	1592	0.92	Moist Tropical	Tall Evergreen
5	24.43	1445	0.99	Dry Tropical	Shrub Savannah
6	24.85	2395	0.61	Moist Tropical	Tall Evergreen
7	23.67	1831	0.76	Moist Tropical	Tall/Medium Evergreen
8	23.97	2190	0.65	Moist Tropical	Tall Evergreen
9	24.22	2417	0.59	Moist Tropical	Tall Evergreen
11	27.09	1900	0.84	Moist Tropical	Low Evergreen Moist

MAAT: Mean Annual Air Temperature (°C)

MTAP: Mean Total Annual Precipitation (mm)

PER: Potential Evapotranspiration Ratio

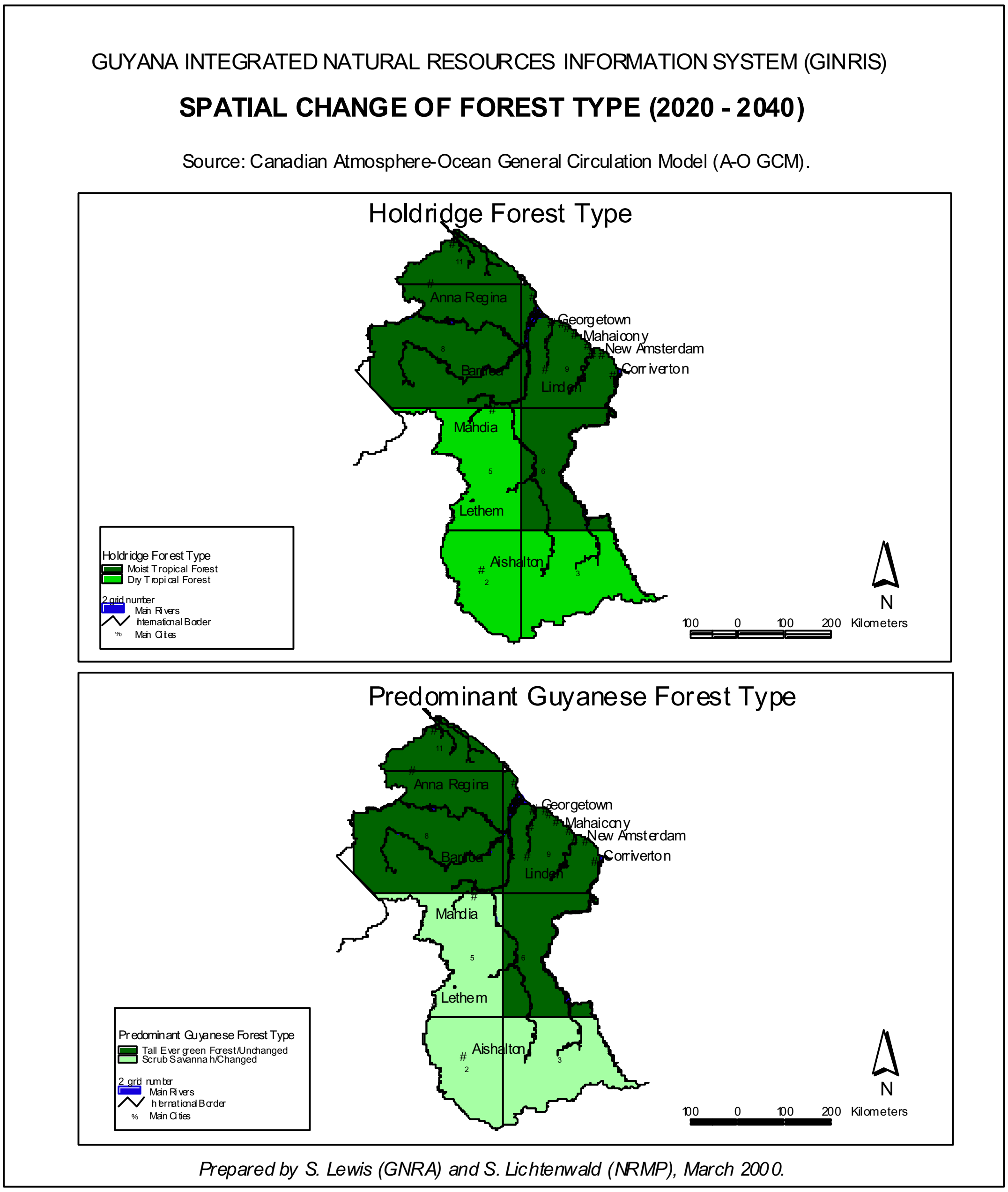


Figure 5.16: Projected change in Forest Distribution under the 2 x CO_2 Climate Scenario.

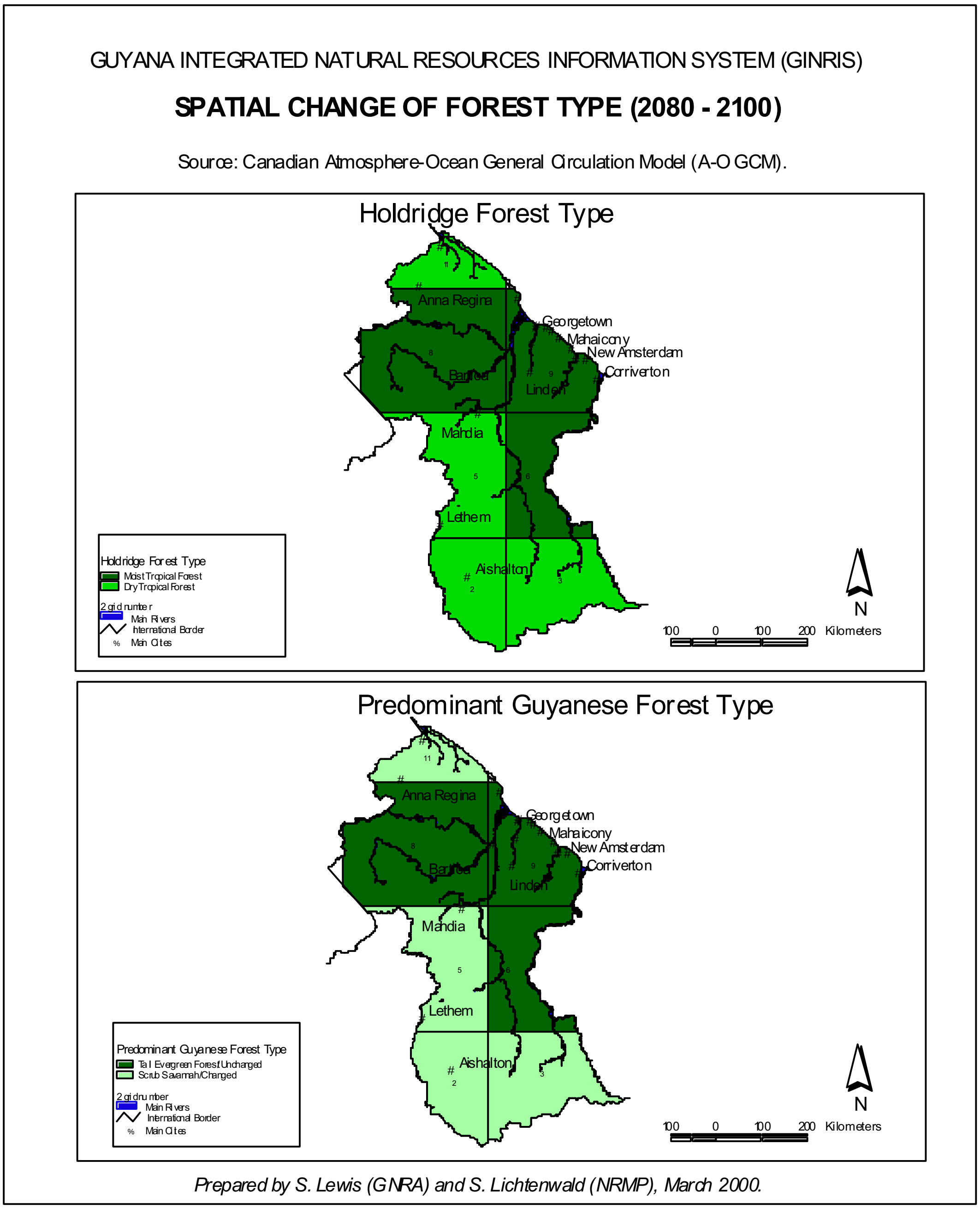


Figure 5.17: Projected Change in Forest Distribution under the 3 x CO_2 Climate Scenario

5.3.5 Vulnerability of the Coastal Zone

5.3.5.1 The Coastal Plain (Extracted from Khan and Sturm, 1994)

The coastal plain extends from Punta Playa at the Venezuelan border in the northwestern part of the country to the Corentyne River, which is its eastern boundary. The length of the coast is approximately 430 km, of which 360 km are maintained, including the islands of Leguan and Wakenaam – see Figure 5.18.

In their natural state, the coastal lands comprised swamps caused by the overflowing of the many rivers passing through or by flooding from the sea. To reclaim the coastal lands, lying at a level of 0.5-1 m below the level of spring tides, a system of dykes was constructed to form polders. The empoldered land was thus protected from flooding by the sea and segregated from the remaining swamps.

At the boundaries of each polder or estate, dams were built at right angles to the shoreline extending backwards to the dam closing off the polder from the remaining swamps. For irrigation purposes this backdam was provided with water inlets. At the seaward side the polders were protected by a dam situated on the shore ridge. The foreshore in front of this dam in general consisted of a mangrove belt a few hundred meters wide. In the sea dam sluice gates were built to obtain gravity drainage at low tide.

As the foreshore, mangrove belt, shore ridges and sea dams eroded from time to time and as the cost to maintain the defences under adverse conditions became greater, the proprietors would retreat inland and build a new sea dam and sluice gates. This policy still continues today where there is land available for retreat. In built-up areas however, a general policy of maintaining the sea defences in their existing position, by the construction of rigid defences consisting of concrete seawalls, has been followed over the last decades.

1

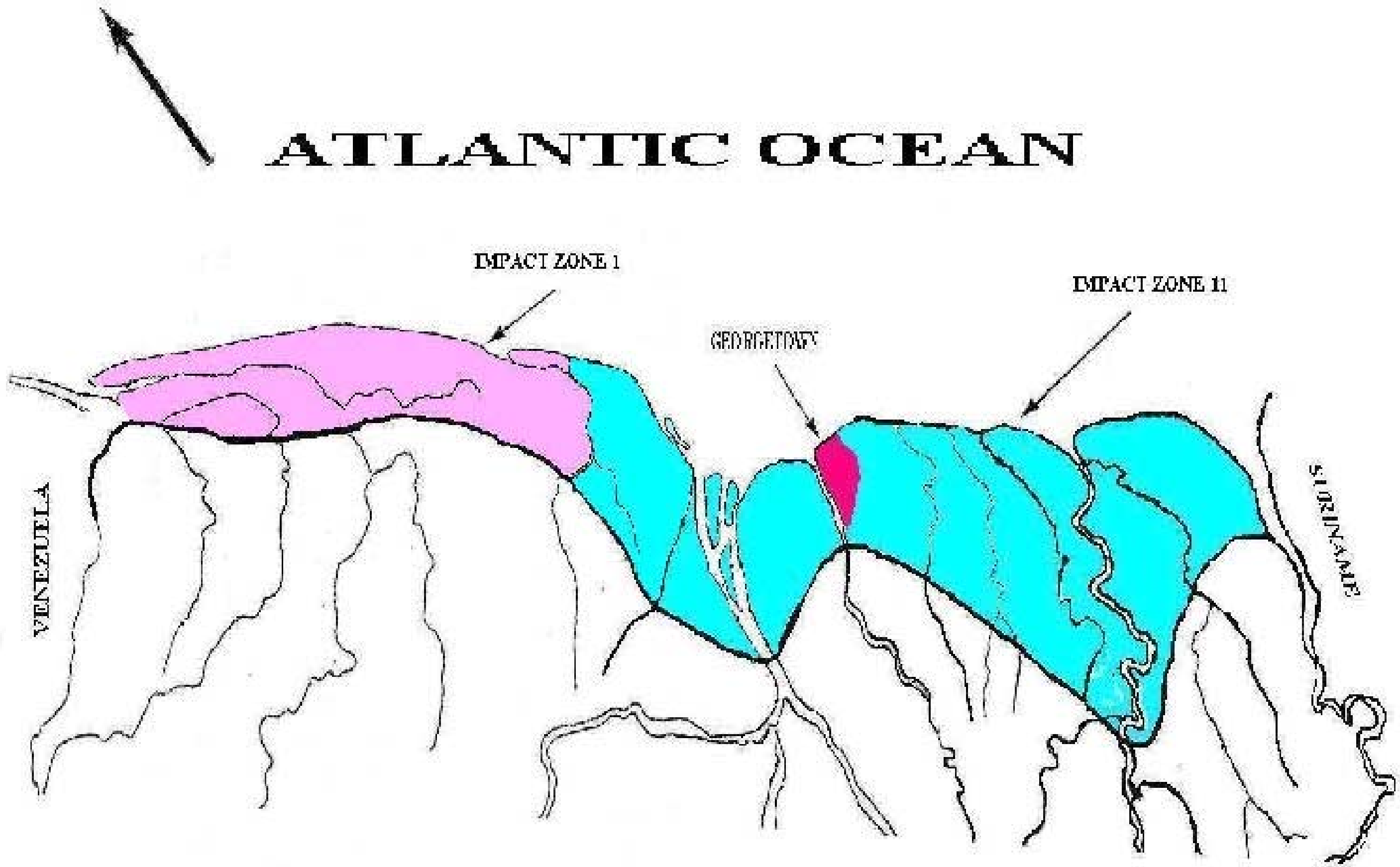
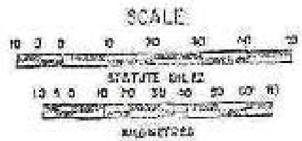


FIGURE 5.18
IMPACT ZONES

IMPACT ZONE 1: NOT PROTECTED
IMPACT ZONE 11: PROTECTED BY SEA DEFENCES



At present about 110 km of coastline is protected by these concrete defences, 250 km by a mangrove belt backed up by an earth embankment and 70 km by natural sand banks. Addressing coastal vulnerability is important for Guyana because the coastal zone is vital since over 90 % of the population reside there and the important economic activities are located there – see Figure 5.19.

5.3.5.2 Coastal Morphology (Extracted from Khan and Sturm 1994)

The coastline of Guyana is dominated by the occurrence of large mud-banks travelling along the coast at fairly regular intervals. The banks are composed of very fine sediments originating from the Amazon River some 1000 km away. The coastal plain itself is composed of similar clays but derived from the Pre-Cambrian Guyana Shield. Its great age ensures that erosion products are low, in spite of the presence of many large rivers. It has been estimated that 5-10 million tonnes/year of silt is carried by the rivers into the coastal system compared with 100 million tonnes/year moving along the shore.

The banks move along the coast in a series of waves or macro-ripples at an average rate of some 1.3 km/year. The macro-ripples have an average length of about 40 km. Thus, a trough or crest will pass a given point on the coast about once in 30 years. The deeper water in the troughs between two banks will provide passage in the direction of the coast for higher waves from the wave trains of the Atlantic Ocean generated by the Northeast Trade Winds. This effect will be strengthened due to refraction and concentration of wave energy through the trough. The increased wave attack often causes erosion of the foreshore (DHV 1992).

The highest waves breaking on the sea defences rarely attain a height of more than 1.5 m. As such the wave attack occurring along the coastline of Guyana can be described as minor. These circumstances combined with the regular, relatively small tidal variations and the absence of storms, storm surges and tsunamis constitute a mild marine environment.

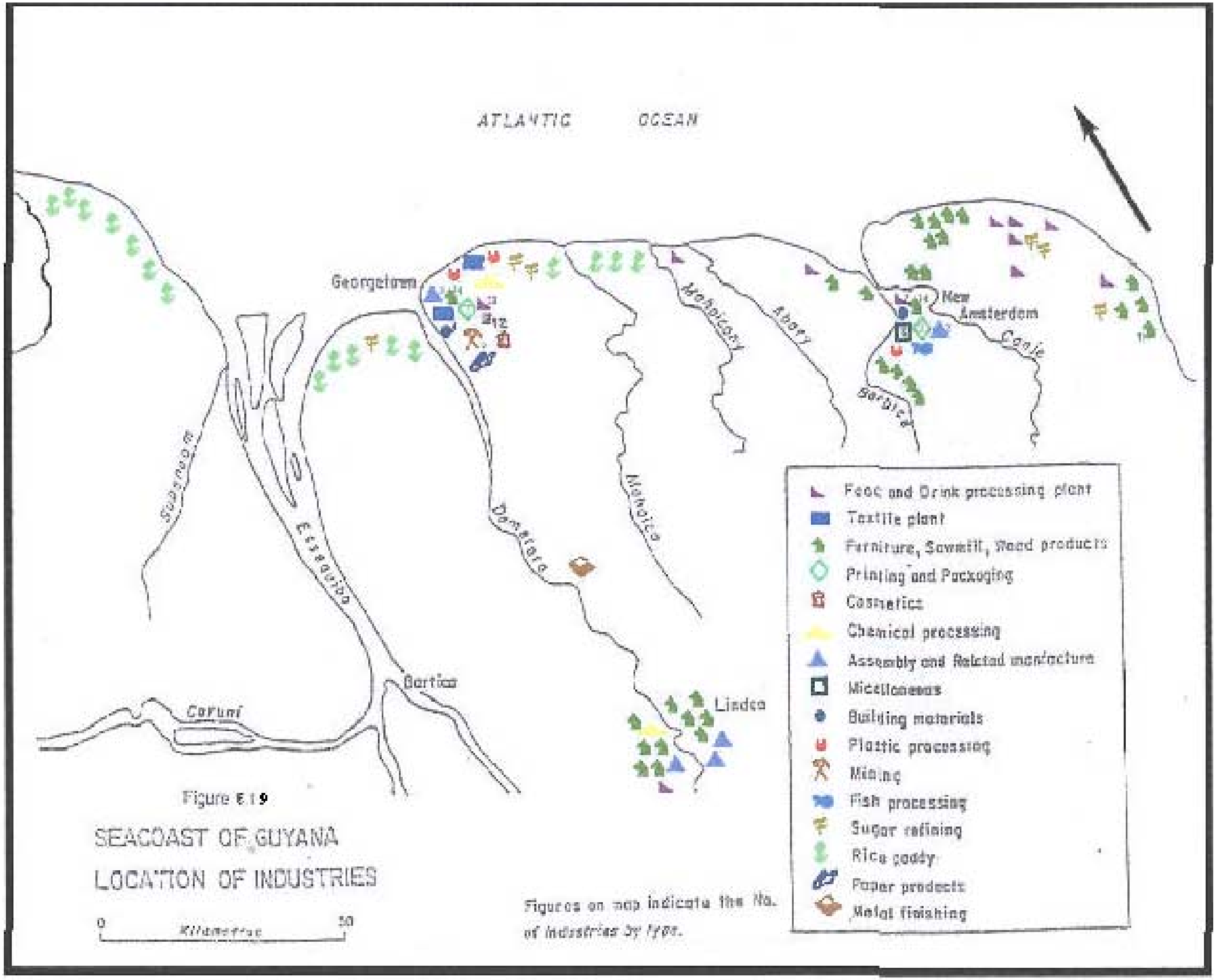


Figure 6.19
SEACOAST OF GUYANA
LOCATION OF INDUSTRIES

Serious erosion does not always take place in front of the trough. Local circumstances such as the occurrence of "sling mud", a highly viscous mud in suspension dampening the waves, the width of foreshore at mean high tide, the type of beach material and variations in the level of the foreshore prevent severe erosion in many cases.

Accretion and growth of the mangrove belt might occur when, due to the passage of the higher part of the mud-bank, the level of the foreshore rises. As in the case of erosion, accretion of the mangroves does not always take place. Actually, the regular pattern of travelling mud-banks and a 30year cycle of erosion can be observed only along the coasts of East Demerara and East Berbice. In the other areas, the influence of the Corentyne and the Essequibo rivers distorts this pattern to a great extent.

Erosion, comprising essentially a lowering of the near-shore zone and higher waves, affects the coast in different ways dependent on the nature of the foreshore. Where the shore is overgrown the roots of the mangrove trees become exposed and the mangrove area will start to suffer from increasing wave attack for which it is not designed. Strengthening of the seaward side of the dam by providing a slope protection is required if it is decided to maintain the existing line of defence. Due to this process, the length of permanently defended coastline is continuously increasing.

It has been attempted in the past to predict in the medium to long term where areas of erosion are likely to occur in order to reserve the necessary funds and make the preparations required. As indicated above serious erosion is generally co-incident with the passage of a trough. Consequently, such forecasting would only be possible along stretches of coastline where mud-banks can be clearly identified although the randomness of the erosion phenomenon reduces the usefulness of this activity.

There are indications that over the last decades accretion does not balance erosion along the Guyanese coast and that there has been a general retreat of the coastline. At locations where permanent sea defences are present the regression of the coastline will be halted.

5.3.5.3 Condition of Sea Defences

The existing sea defences are generally in a bad condition. Rehabilitation and reconstruction programmes for the medium term have been developed by consultants funded by international donor agencies, such as European Economic Community, Inter American Development Bank and World Bank. The Sea and River Defence Division of the Guyanese Ministry of Public Works and Communication is being supported in managing of the new capital construction works through technical assistance programmes funded by the international agencies.

5.3.5.4 Drainage System

Generally drainage of the polders is carried out by gravity flow during periods when sea or river levels experience low tides. The period of discharge is conditioned by the level of the land to be drained relative to the mean sea level at the outfall and by the tidal amplitude. Gravity drainage sluices typically discharge for 7 to 14 hours in every 24 hours due to the various hydraulic and morphological conditions. A rise of the sea level will reduce the discharge period.

Presently pumped drainage is required in some areas, especially at the sugar estates of the East Coast Demerara and the Corentyne Coast. In future conditions, demands for pumped drainage will increase and this will impact heavily on the economic development of the country. Drainage and irrigation problems constitute one of the main reasons for low agricultural productivity, particularly in rice production, (Hunting 1997).

5.3.5.5 Climate and Hydrology Factors

The most important climate factor is global warming. As previously indicated, the GCMs are indicating that temperature will rise in Guyana. The record has also shown that temperature has already risen on Guyana's coast. There has also been an indication that sea level has risen and is expected to show an accelerated rise.

Because of the interactions among the components of the climate system, coastal agriculture and fishery may be affected by the expected rise in temperature. Sea-surface temperature changes may affect the marine environment and the climate on the coast. Coastal agriculture will have to contend with persistently higher air and soil temperatures and modified air and soil moisture levels. Rain-producing systems can change resulting in changes in the availability of water for irrigation. Because it is expected that the number of storms will be less but more intense, flood management will become critical in the entire coastal belt.

There is no evidence of a geological component of subsidence (see National Circumstance). However, a preliminary study by John Bassier (1976), ref. Camacho 1988, found that Georgetown may be subsiding at a rate of about 10 mm/yr. He reasoned that the major ground water aquifers are not rechargeable and that the subsidence is due to the "mining" of ground water.

Fishing is done within about 20 km of the coastline. Fishing yields are relatively high and sufficient to satisfy local demands as well as export. There has been no report that nutrient discharges from agricultural lands have significant effects so far on the fish population and on other ecosystems.

Coastal forests are mostly located in the northwestern part of the coastal belt and are very rich in biodiversity. Deer, turtle and several species of birds can be found here.

5.3.5.6 Impact Zones (Extracted from Khan and Sturm, 1994)

Figure No. 5.20 presents a frequency distribution of monthly high water levels at Port Georgetown in the period 1970-1980. The effects of accelerated sea level rise (ASLR) are included. It shows the "flatness" of the curve and subsequently the great increase of the frequency of occurrence for a particular water level. The impact of the ASLR will affect the coastal area in different ways. The coastal area of Guyana is therefore subdivided into two impact zones according to the differences in the population density and the nature of the coastal protection (Figure 5.19). Those two impact zones are:

Impact Zone I: the coastal belt of this region mostly comprises mangrove swamps and its people already know the problems, which come with flood waters. Transportation is mainly by boats and canoes. Houses are built very near to the river water line. The shoreline is expected to retreat with a rise of the sea level and this retreat can be as much as 2.5 km with a rise of 100 cm.

Impact Zone II: in this densely populated region, comprising several islands, there is a combination of concrete and earthen sea defences. The problem of inadequate maintenance of the sea defences has become evident and substantial breaches and overtopping have occurred.

In both zones, the matter of drainage is a current problem. It is therefore necessary that the entire Drainage and Irrigation System be revisited with a view towards implementation of measures to alleviate the almost yearly problem of inadequate drainage during the rainy seasons and during ENSO cold phases.

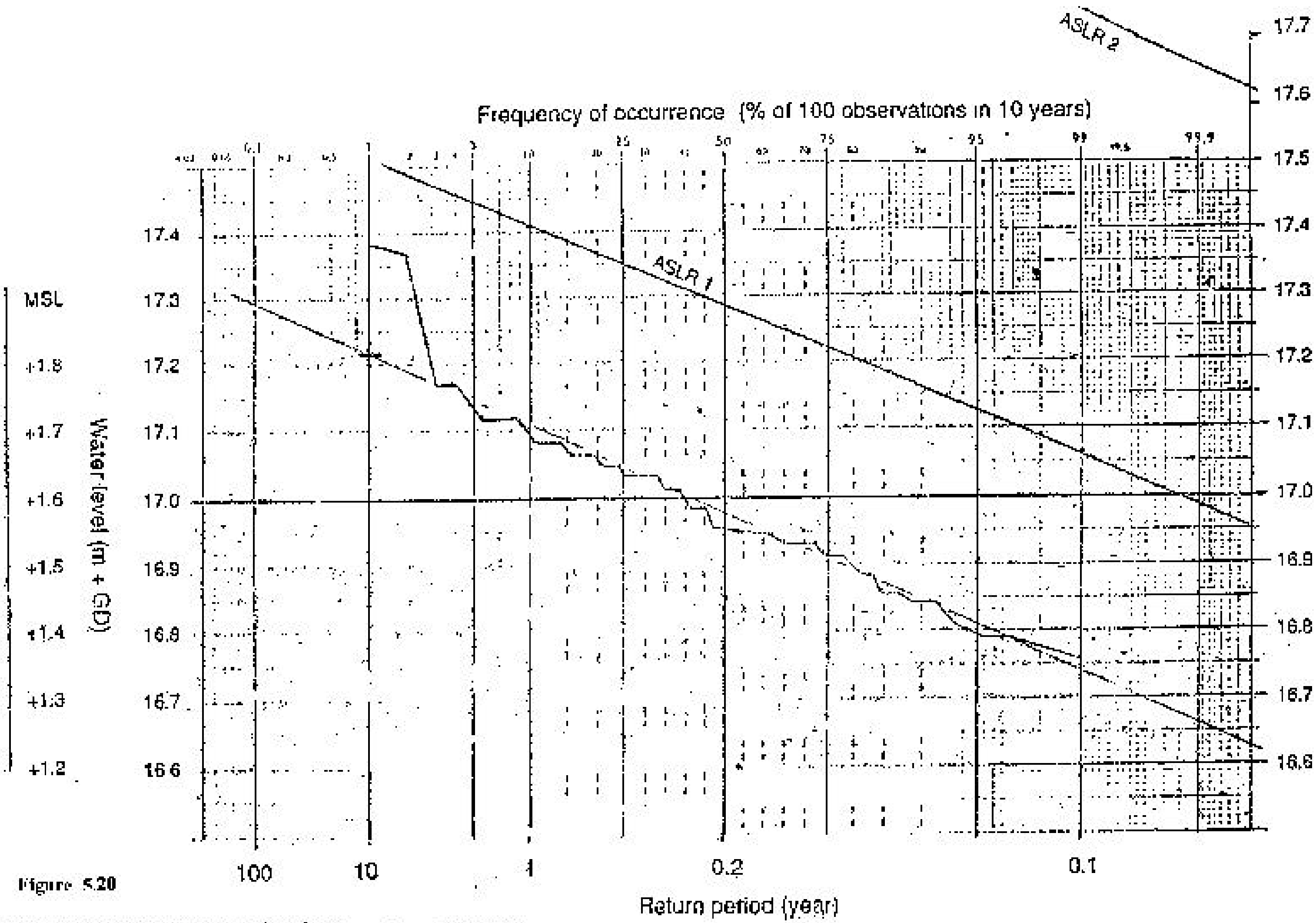


Figure 5.20

Monthly High Water level Readings for Georgetown 1970-1980

ASLR 1: 0.3 m ; ASLR 2: 1.0 m.

5.3.5.7 Submergence and Inundation of Coastal Wetlands

The most direct impact of a rise in sea level for Guyana would be the inundation of areas that had been just above the high water level before the sea rose. Coastal wet lands are generally found at elevations below the highest tide of the year and above mean sea level. Thus, wetlands account for most of the land less than 1 m above sea level.

Mangrove forests are found at the interface between the terrestrial and marine ecosystems. They are also found in estuarine wetlands and in tidal reaches of riverine areas. The main species of mangroves found in Guyana include Avicennia germinans (Black mangrove), Rizophora mangle (Red Mangrove), and Laguncularia racemosa (White mangrove). A.germinans known locally as "Courida" is accepted as the main species in the region. Large sections of the Atlantic coast from the Corentyne to the Essequibo Rivers have become monoculture stands of Avicennia.

Mangrove ecosystems are an important coastal resource having a variety of functions and uses, including:

- **Bee keeping**: Approximately 75% of the honey produced in the country is from mangrove areas.
- **Fisheries**: The mangrove swamps are natural breeding and nursery grounds for brackish water shrimp and fin fish species. Estimates of fishing harvest based on mangrove-dependent species are important.
- **Wood**: This is one of the most important uses of mangroves because it provides an easy source of fuel wood. It is used domestically for cooking, for making fences, tents and arbor for gardens.

In addition to their economic use, mangroves play an important role in coastal protection and sea defence. Depending on the width of the strip of mangroves, they can act as barriers to diminish or buffer wave action. Therefore, they play an important role in protection of the sea wall or embankment and reduction of damage to the sea defence system. Mangroves also help to accelerate the process of deposition of soil particles, which are suspended in tidal water thereby raising the level of coastal lands in the intertidal zone.

Mangroves also provide a habitat for a number of different species of phytoplankton, shrimps, crab and manatee as well as birds.

Mangroves are being increasingly threatened in Guyana today. It is unclear which agency has the mandate for mangrove protection and management. As such the use of mangrove forest is not monitored or regulated. There is also a lack of current data on the status of mangroves in terms of distribution, extent and removal. Furthermore, there is a lack of public awareness regarding the importance of mangroves. This makes management of this invaluable resource very difficult.

Much of the destruction of mangroves resulted from conversion of these ecosystems into other uses. This is attributed to mangroves being viewed as wastelands, useless unless converted or exploited directly for cash products. For example, the cutting of mangroves for fuel wood is not done in a sustainable manner. The practice is not supervised and trees are badly damaged in the process. Fishermen also cause local damage by pulling up boats on mudflats in some areas, creating paths through the mangroves. Mangroves are also affected by natural processes such as the cycle of erosion and accretion along the coast. As a result, there is considerable loss of foreshore and mangroves become affected in the process.

While mangroves are likely to play an important role in reducing the impacts of sea-level rise by protecting the coast, this ecosystem may itself be seriously affected by sea level. It seems that mangroves find it hard to cope with rapid sea level because it endangers their way of interacting with the surrounding environment of trapping sediment with their roots. If the sediment is washed away, then the swamp cannot be formed. Instead, what can be observed are individual trees or thin patchy areas in which they cannot survive.

Marine animals, which are of economic importance to man, feed directly on detritus (i.e., shrimps) or feed on detritus feeders (i.e., fish and crabs). Without mangrove and other coastal fringe ecosystems, neither the habitat nor adequate food to support these ecosystems will be available and these populations will decline.

For the rates of sea level rise of the last several thousand years, marshes have generally kept pace with sea level through sedimentation and peat formation. As sea level rose, new wetlands formed inland while the seaward boundary was maintained. Because the wetland area has expanded, one would expect a concave marsh profile, i.e., that there is more marsh area than the area found immediately above the marsh. Thus, if sea level rose more rapidly than the marsh's ability to keep pace, there would be a net loss of wetlands. Moreover, a complete loss might occur if protection of developed areas prevented the inland formation of new wetlands.

5.3.5.8 Coastal Erosion

Processes other than sea level rise also contribute to erosion, including storms, structures, currents, and alongshore transport. Greater wave energy associated with higher sea level will cause increased rates of beach erosion and coastal land loss. Rates of retreat will be influenced locally by a range of factors including nearshore bathymetry, incident wave energy, wave amplitude spectra, wave approach direction, physico-chemical, geologic and morphologic properties of shoreline materials, sediment transport pathways, production rates and sources of eroded sediments.

Sea level rise can also result in the loss of land above sea level through erosion. Bruun has shown that the erosion resulting from a rise in sea level would depend upon the average slope of the entire beach profile extending from the dunes out to the point where the water is too deep for waves to have a significant impact on the bottom (generally a depth of about 10 meters). By comparison, inundation depends only on the slope immediately above the original sea level. Because beach profiles are generally flatter than the portion of the beach just above sea level, the "Bruun Rule" generally implies that the erosion from a rise in sea level is several times greater than the amount of land directly inundated. Bruun found that a 1-cm rise in sea level would generally result in a 1-m shoreline retreat, but that the erosion could be as great as 10 m.

The potential erosion from a rise in sea level could be particularly important to recreational beaches, which include some of Guyana's most economically valuable and intensively used land. Relatively few of the most densely developed beaches are wider than about 30 m at high tide. Thus, the rise in relative sea level of over 60 centimeters projected in the next 40 to 50 years could erode most recreational beaches in developed areas, unless additional erosion response measures are taken.

In Guyana, beach profile measurements collected at a number of beaches show that, while erosion rates, as measured by the retreat of the high ground above the high water mark may be as high as 1.5 meters during a four year period in some cases (See Figure 5.21), accretion, which occurs mainly in mudflats and at the base of shoreline protection structures, may also be as high as 0.5 meters per year as measured at one location (See Figure 5.22).

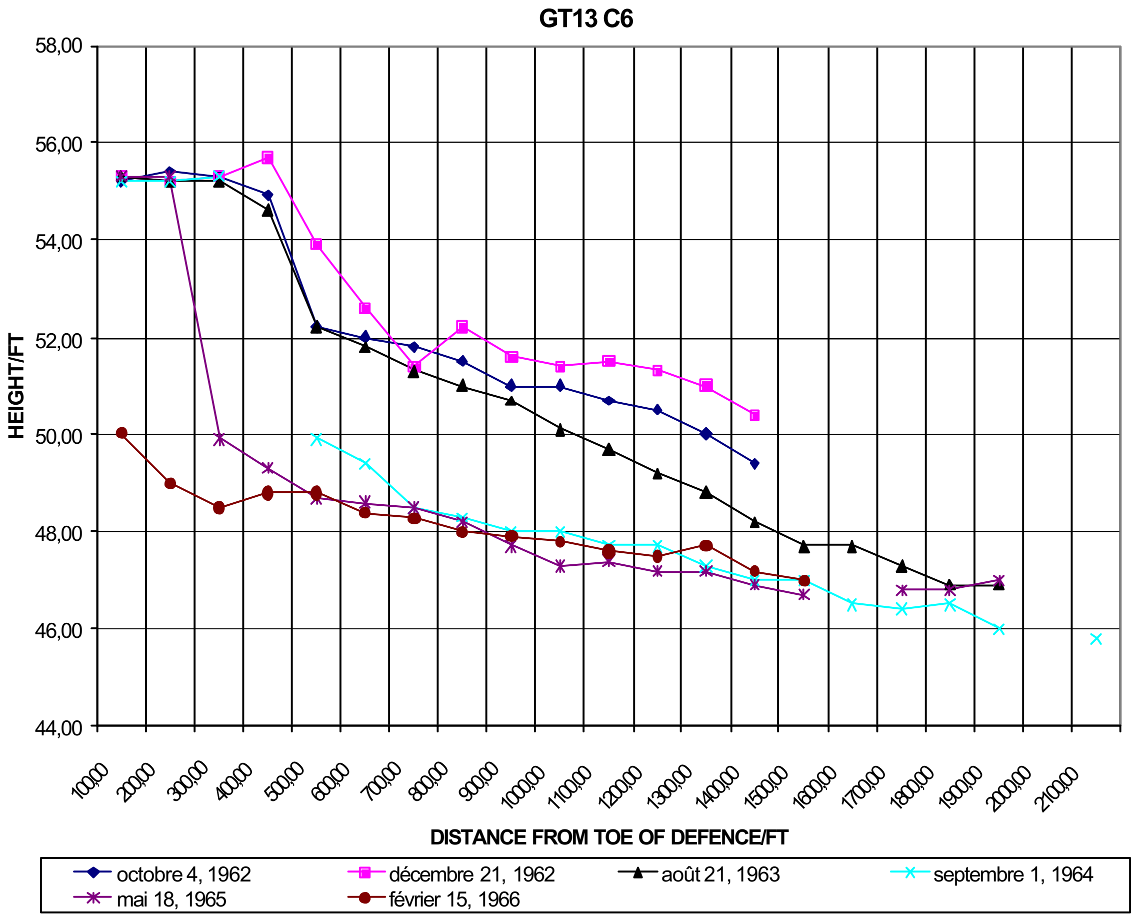


Figure 5.21: Evidence of Beach Erosion in Coastal Guyana

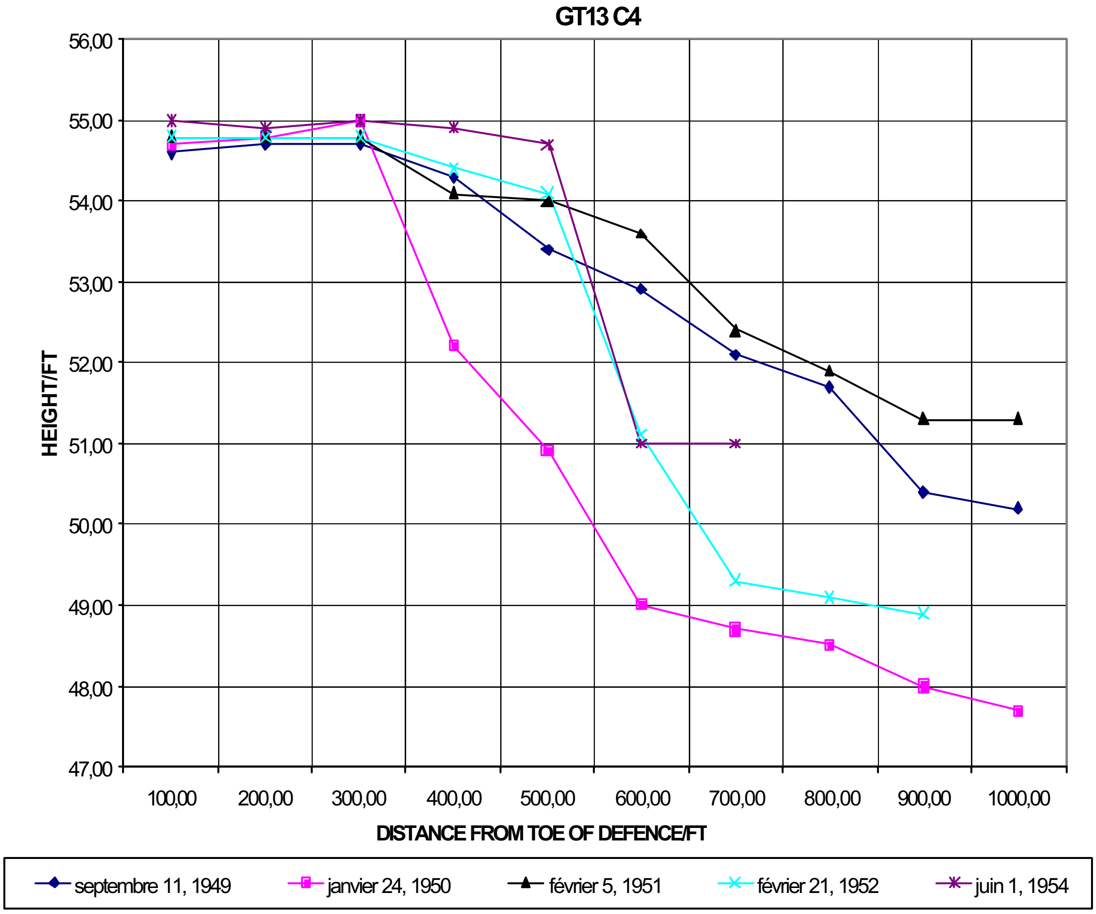


Figure 5.22: Evidence of Coastal Accretion in Guyana

5.3.5.9 Flooding and Storm Damage

A rise in sea level could increase flooding and storm damages in coastal areas for three reasons: erosion caused by sea level rise would increase the vulnerability of communities; higher water levels would provide storm surges with a higher base to build upon; and higher water levels would decrease natural and artificial drainage. This problem has been highlighted in sections 5.3.5.6 and 5.3.5.8.

In addition to community-wide engineering approaches, measures can also be taken by individual property owners to prevent increased flooding. In Guyana, there is neither a government policy in place to restrict development along the coast nor a National Flood Insurance Program to encourage communities to avoid risky construction in flood-prone areas.

5.3.5.10 Increased Salinity in Estuaries and Aquifers

Although most attention is focused on the increased flooding and shoreline retreat associated with a rise in sea level, the inland penetration of salt water could be important in some areas, especially in the flood-prone coastal region of Guyana, where the greatest portion of population and economic activity are located.

A rise in sea level increases the salinity of estuaries like the Demerara, Berbice and Corentyne rivers of Guyana, by altering the balance between freshwater discharges and saltwater intrusion.

The salinity of an estuary represents the outcome of, (1) the tendency for the ocean salt water to completely mix with the estuarine water and, (2) the tendency of fresh water flowing into the estuary to dilute the saline water and push it back towards the ocean. During droughts, the salt water penetrates upstream, as has been observed in the estuary of the Canje river, while during the rainy season, low salinity levels prevails. A rise in sea level has an impact similar to decreasing the freshwater inflow. By widening and deepening the estuary, sea level rise increases the ability of salt water to penetrate upstream.

Saline intrusion will most severely impact the rivers. This is because the density of seawater is higher than river water and therefore this will allow intrusion of saline water higher upstream of rivers. Furthermore, the conservancies are likely to be affected by a rising sea level as well. The economy of the country, which is quite dependent upon agriculture, can be severely affected in the wake of a rise of sea level. Coastal aquifers, whose water tables are close to or below mean sea level, can also be subject to saline intrusions. If these aquifers are exploited for drinking water or agricultural use, then climate-driven sea level rise may create negative impacts for these sectors.

5.3.5.11 Water Resources

Water supply for domestic, industrial and commercial purposes are abstracted from about 170 wells drilled mainly from two aquifers known as the “A” and “B” sands. The water is distributed through a network of pipes estimated at about 3000 miles, laid in urban and rural areas along the coastal plain.

The drainage system is natural and depends on the main rivers, which extend beyond the coast – see Section 5.4.5.2. The major rivers include Essequibo, Demerara and Berbice. Smaller rivers such as Mahaica, Mahaicony, Abary and Canje are also part of the drainage network. All these rivers are within tidal influences of the Atlantic Ocean and this effect is noticeable for some distance upstream. Sea-level rise will exacerbate this condition.

Additionally, to facilitate the country’s agricultural output, irrigation waters are also supplied from water conservancies (i.e., reservoirs). There are four conservancies along the coastal plain: Boerasirie, East Demerara, Tapakuma and Mahaica/Mahaicony/Abary. In the Corentyne, irrigation water for rice, sugar and other crops, is extracted by a number of pump stations along the Canje River in its lower 50 km stretch (which is vulnerable to saline intrusion). This practice can be found on some of the smaller rivers.

The majority of the population is concentrated in a narrow strip along the Atlantic coast. Their main supply of water is the wells located in close proximity to the coastline and therefore the risk of salinization of these coastal wells is highly likely with any sea-level rise.

Seawater intrusion is a common phenomenon today in coastal aquifers. Although Guyana’s coastal aquifer is characterized by some favorable conditions, such as the fact that the clay percentage increases gradually northwards possibly sealing the aquifer from the sea, the risk of salinization due to sea water intrusion should not be ignored. Over-exploitation of the “A” sand's aquifer results in the decline of their piezometric head, as exemplified within the Georgetown area. This might result in a leakage from the upper sand into this aquifer causing further seawater intrusion into the already saline water bodies of the upper sands. Saline water can then migrate downward into the aquifer creating the conditions of an inland moving interface. A similar process might take place between the “A” and “B” sand aquifers.

5.3.5.12 Agriculture

Agriculture is the dominant economic activity on the Guyanese coastal plain. The coastal belt has favourable soil and climate for lowland crops such as sugarcane and rice. Agriculture is a major source of employment, economic growth and foreign exchange in Guyana. In 1997, the Gross Domestic Product (GDP) for agriculture was G$ 53.6 billion (US $297.8 million). The economic contribution of this sector to the national economy is vital and hence the need for sustaining its vitality cannot be overemphasized (Khan and Rahaman, 1998). Almost all of the agriculture products important to national economics are harvested along the coast.

5.0 IMPACTS AND VULNERABILITY ASSESSMENT

The impacts of global climate change should not be taken lightly in so far as agriculture is concerned. Inundation and salinization associated with sea-level rise could possibly devastate this activity along the coast.

A direct impact of rising sea levels will be the threat of saline intrusion into cultivation fields. Drainage during the raining seasons may require additional and more intensive pumping facilities. The possible intrusion of salt water into the water conservancies and estuaries needs to be examined since these are the prime source of irrigation water.

If weather systems become more intense, then the effect of flooding conditions must be addressed. More frequent El Niño/La Niña events can subject the coast to cycles of drought/flood which can have serious effects on the soil and, therefore, on food production. Cattle and other livestock may not be spared because of the severity of the conditions associated with these rainfall extremes. Apart from the effect on rice and sugar, scarcity of cash crops will be a problem and an economic hindrance.

5.3.5.13 Fisheries

After agriculture, fisheries is the second most important economic activity along the coast. About 6.5 million tonnes of fish were exported in 1998 comprising about 6% of the nation's GDP. The value of fish and fish products for local needs has been also recognized by the Government. The fishing industry has four sub-components: industrial, artisanal, inland aquaculture and ornamental.

Vulnerable resources to sea level include the fish resource itself, wharves/landing sites, co-operative buildings, fishers and mangroves.

More severe and frequent flooding will cause the potential destruction of landing sites and cooperative buildings that are situated along the coast. Fishers must have a place to land their catch for market purposes and this must be a place that is clean and healthy since most of the fish and shrimp caught in Guyana are exported.

The readjustment of mangroves will also affect the fish resources since some of the species caught have nursery areas in the mangroves. If the mangrove forest has to re-establish itself at a new location then valuable fish resources will be lost. At the local level, persons living in rural areas also depend heavily on fish as their source of protein. Hence, a decrease in fish production can see many persons not having this essential nutrient since other alternative sources of protein can be too expensive.

Disruption of coastal and marine ecosystems will also have an effect on species being caught. The Chinese seine fishers will have to move their fish pens nearer to the shore since most of the target species will be closer to the shore. This will include building new fish pens since the older ones will be lost to more frequent flooding or permanent inundation. Biological studies should be conducted to assess the differences, if any, on the biology of the fisheries, checking for growth patterns for example.

Freshwater aquaculture will be impacted from salt-water intrusion. While some species are salt tolerant to some degree (i.e., various Tilapine species) others are not (i.e., hassar). In addition to freshwater species, brackish species will also be impacted on by flooding and erosion caused by sea-level rise. Pond banks will eroded away and cultured fish will escape. Extensive flooding of soil will leach away nutrients, resulting in poor carrying capacity of ponds under extensive and semi extensive production. The introduction of predacious species via flooding into culture operations will result in the inability to practice aquaculture unless painstaking drying and removal activities are carried out. Aquaculture will no longer be a financial viable operation if the introduction of predators cannot be controlled.

5.3.5.14 Human Settlement Infrastructure

Human settlement and infrastructure that are concentrated in the coastal zone of Guyana would, in all likelihood, be vulnerable to climate-driven sea level rise.

5.0 IMPACTS AND VULNERABILITY ASSESSMENT

Guyana has a population of about 750,000 inhabitants, 90% of which reside on the coastal plain. The population is concentrated in certain locations influenced by the availability of land for housing and other utility services. Higher population densities are observed in Georgetown, the capital city and adjoining areas due to the proximity and closer links with the important urban centre. Major highways and secondary roads are also concentrated on this narrow coastal strip. Georgetown is served by a conventional main sewerage system, which consists of 24 sewerage basins each draining to a dedicated pumping station. In the rest of Georgetown and the coastal plain, sewerage is discharged into septic tanks or pit latrines.

There are developed housing schemes and squatter settlements. This latter has its root in the rural areas where socio-economic conditions are poor and extended households are overcrowded. The Government has improved the allocation of titled house lots but the capacity to accelerate the allocation process is weak. Another problem lies in the fact that the areas identified, legally and illegally, for housing settlements are all in the vulnerable low-lying coastal zone.

Sea-level rise will cause permanent inundation of the entire coastline if no response measures are taken. Houses will be severely damaged by more frequent flooding. In addition, households could suffer from water borne diseases due to contamination of water. It would also seriously affect communications, medical facilities, and transportation infrastructure, which are the basis for human survival.

Sea-level rise may lead to increased erosion, which would cause damage to the foundation upon which houses are built.

Salt-water intrusion will have similar effects on human settlements as described above. In particular, saltwater intrusion affects plant soil and lumber tends to rot faster.

5.3.5.15 Sluice Gates and Sewer Systems

Sluice gates for draining excess water to the ocean are very common in the coastal region of Guyana, parts of which are already below sea level. Sewer systems provide for drainage of surface water from streets in the event of a rainstorm. The sewer system of the city of Georgetown rely on gravity drainage: water flows downhill from the streets into the sewers, then continues toward some outfall area. Should the sea level rise, it could limit the effectiveness of gravity drainage systems and necessitate the installation of mechanical pumping stations to aid drainage of water. This is already being done at present and, indications are that this type of drainage must be intensified.

5.3.5.16 Highways, Roads, and Bridges

Guyana is divided into distinct physiographic regions by its numerous rivers, notably the Demerara, Berbice and Essequibo rivers. Road transport is very common and there are a number of bridges creating nodal links. A rise in sea level of 0.6 m can inundate, weaken, and erode coastal roads. Low-lying roads would be especially jeopardized during storms, risking the lives of motorists. Bridges would be threatened as well. Rising sea levels can also increase bridge structural load, as well as scour bridge foundations.

5.3.5.17 Human Suffering and Loss of Life

Each year floods bring discomfort and losses to thousands of people throughout the coastal region of Guyana. Despite lessons of the past, people continue to settle and build on the coastal plain. The people of Georgetown and surrounding regions of the coastal plain live behind an elaborate system of sluices and dykes. They are therefore even today very vulnerable to flooding from excessive rainfall and from enhanced sea level rise. Further rise in sea levels would most certainly threaten human lives. Flood losses can also be expected to show higher costs.

5.3.5.18 Tourism

Tourism, which is a minor foreign exchange earner in Guyana, could also be adversely affected by global warming and sea level rise.
Guyana's tourist industry is not as developed as the Caribbean countries and it is mainly centered on eco-tourism in the hinterland of the country.

The climate of Guyana is already warm and humid. Besides, Guyana's beaches are not as extensive as those of the Caribbean Sea or for that matter Brazil. If the climate warms to extend the seasonal use of beach facilities in the middle latitudes, and if temperatures and humidity become overbearing, then Guyana may not have a comparative advantage over the northern countries.

Tourist attractions on the coast of Guyana include Georgetown, the capital city and few beaches. Other major tourist attractions include the tropical rain forest, major water falls and rivers which are concentrated in the hinterland regions and therefore less vulnerable to sea level. Guyana can make use of its hinterland attraction in promoting this sector.

Georgetown is situated on the eastern bank of the Demerara River. Most of the city's historical buildings are wooden structures, reflecting the unique 18^{th} and 19^{th} century architecture and are major tourist attractions. Further, the major administrative facilities, hotels and shopping centers are located in Georgetown making this city the "heart" and "brain" of the country.

In Guyana, there are three major shore types: muddy coasts, shell and sandy beaches.

Mud or clay accretionary coasts start as a tidal flat at the landward end of a shoal and extend as much as 0.8 km. As soon as the tidal flat begins to emerge above the high water level, mangroves establish themselves and stabilize the flat.

Sand and shell material transported toward the shoreline during high water levels are deposited in the foreshore region. Sandy beaches occur on the west bank of river mouths and they are not as extensive as the mudflats. They extend for approximately 50 – 70 m during low tide.

Stretches of beach entirely composed of shell fragments occur in several places along the northwestern coast of Guyana. Their average length is about 1,300 m and they extend for a distance of about 100 m (Daniels, 1981). The landward part of these beaches is very old, but on the seaward side, fresh materials are continuously deposited.

Shell Beach is one of the country's major tourism attractions. This area runs from Waini Point in the mouth of the Pomeroon River on Guyana's northern shore. This is the only beach in the world where four species of sea turtles nest: Leatherback, Green, Olive Ridley and Hawksbill. Most other nesting beaches in the world have only one or two species.

Shell Beach is also an important habitat for a large number of other animal species, some of which are now endangered. Blue, Gold and Red bellied Macaws frequent the Shell Beach forests and the mudflats and mangrove lining the shores home to an impressive number of flocks of the striking Scarlet Ibis. Other birds that can be seen mixing with the common egrets and herons are Roseate Spoon-billed and Caribbean Flamingos. Many of Guyana's mammal species can also be found here, such as manatees, jaguars, tapirs, deer and several species of monkeys.

Other beaches include the Number 63 Village Beach located in Corentyne, and others at Hope, Parika, Bushy Park, and Unity Beach. These places are both used for religious and recreational activities. A major part of the Guyanese population is Hindus for whom cremation of the dead is a part of their funeral rites. Hindus conduct the burning of the dead on the beach. They also perform ceremonial rituals on the beach since they hold the ocean to be sacred. These beaches are also used for picnics and playing sports especially during weekends and public holidays.

Georgetown and coastal centres of attraction can be vulnerable to accelerated sea level rise. Rising temperatures and humidity will not help to promote beach activities. In the hinterland, river characteristics may change leading to sites of attraction being modified. However, there may very likely be other newly emerging sites of attraction.

However, successful tourism depends on efficient communications, transportation, networks and other social services. It may be required to have substantial investments in these areas.

5.3.6 Health Effects

Much of what is known concerning how climate change might affect human health has been inferred from correlation of health conditions with weather variables or seasonality. Recent studies have focused on the possible impact that changing climate, season, and weather variables might have on the incidence of disease.

Clear links have not yet been established between climate change and human health. Probably modest effects on human health, however, could occur through:

(1) the direct impact of temperature (heat stress and cardio and cerebro-vascular conditions related to temperature extremes);

(2) climate-related chronic, contagious, allergic, and vector-borne diseases (e.g., malaria and dengue fever); asthma and hay fever, linked to plants or fungi whose ranges and life cycles are strongly affected by climate and weather; and mosquito and tick-borne diseases, such as encephalitis and Lyme disease, especially where conditions are already warm and humid, with poor drainage, as in the coastal region of Guyana;

(3) premature birth, which has an adverse effect on human reproduction;

(4) pulmonary conditions such as bronchitis and asthma related to urban and rural smog that may increase with climate change; and effects of increased ultraviolet radiation on suppression of the immune system - See Table 5.15.

While there is a lack of data in Guyana, there have been reports that skin cancer is on the rise in a region of Guyana inhabited mostly by Amerindians (region 9). This phenomenon seems to suggest that Amerindians, who are repeatedly exposed to solar radiation, are being affected by higher incidences of UV-B radiation and possibly higher surface temperatures.

Table 5.15: Potential Health Impacts of Climate Change in the Coastal Plains of Guyana

Health Impact	Climate Variable Sensitivity	Agent	Vector	Threshold	Increase in Diffusion
Vector-borne Diseases					
1. Malaria	-temperature -rainfall -humidity	Plasmodium	Anopheles mosquito	20 - 30 ^{O} C	+++
2. Dengue Fever	-temperature -rainfall -humidity	Virus	Aedes mosquito	20 - 30 ^{O} C	++
3. Yellow Fever	-temperature -rainfall -humidity	Virus	Aedes mosquito	20 - 30 ^{O} C	+

4. Encephalitis	-temperature -rainfall -humidity	Virus	Mosquito	20 - 30 ^{O} C	+
5.Onchocerciasis	-temperature -rainfall -humidity	Onchoerca Volvulus	Black Fly	20 - 30 ^{O} C	+
Other Infectious Diseases					
1. Cholera	-water temperature	Bacillus	Water	20 - 30 ^{O} C	++
Other Health Outcomes					
1. Climate stress mortality	-temperature -humidity	_	_	33 ^{O} C	+++

+++ very probable; ++ probable; + possible
(adapted from IPCC, 1995; WHO, 1990)

Climate-induced effects on other sectors such as agriculture, fisheries, water and coastal resources, and social and economic conditions might also affect human health. Decreases in food production might result in poorer diets, and rise in sea level and changed precipitation patterns may result in the deterioration of water supplies. Greater numbers of humans could migrate from one area to another, changing the geographic ranges and susceptibility of human populations to many diseases. In general, any event that reduces standards of living will have an adverse impact on human health.

5.3.7 Conclusion

It is evident from the above then, that if anthropogenic climate change were to occur in the manner that AO-GCM's are predicting, several key sectors of the Guyanese economy, including agriculture and forestry, can be adversely impacted. In the forestry sector climate change would influence the distribution of forest species, with savannah replacing more valuable forest stocks in the interior. This change in forest stocks would furthermore compromise the ability of Guyanese forests to act as a removal sink for excess atmospheric CO_2. In agriculture, the yields of sugarcane and rice, the two most economic crops, risk losses under the warmer and, most likely drier, climate of the future.

Guyana's greatest vulnerability to climate change however, is the risk of flooding and inundation deriving from sea level rise in the coastal zone. Most of Guyana's population and economic activities are concentrated in this narrow, fragile, and currently stressed zone. The area is already, for the most part, below the high tide water level. An increase in sea level of about 60 cm then, as projected by AO-GCMs, would further exacerbate the vulnerability of this already fragile zone.

Policy decisions, backed by detailed studies into the response mechanisms required to adapt to the adverse effects of climate change, will be required. These decisions ought to address the direction in which coastal zone development will proceed in the future. That is, should coastal Guyanese ACCOMMODATE, PROTECT OR RETREAT?

6.0 ADAPTATION MEASURES

CHAPTER SIX

ADAPTATION MEASURES

The signals of the impacts of climate change are being noticed in Guyana, especially in its coastal zone. Adaptation measures will necessarily range from general capacity building to sector-specific capacity building and projects. Adaptation responses will also have to include public awareness, education and training and must focus on sensitizing the local communities on the impacts of anthropogenic climate change and the response mechanisms to be used to address local vulnerabilities.

Successful adaptation depends upon technological advances, institutional arrangements, availability of financing, and information exchange, (IPCC, 1995). This IPCC statement is the key towards having Guyana address its vulnerability to climate change successfully. Guyana will be unable to do so unless the necessary financial and technical assistance is provided.

An aerial view of a section of coastal Guyana

6.0 ADAPTATION MEASURES

6.1 INTRODUCTION

Adaptation is concerned with responses to both the adverse and positive effects of climate change -IPCC, 1992. It has to do with responses to expected or actual happenings that are associated with anthropogenic climate change and seek to reduce damages and loss of lives in the short-term and in the longer-term. It is best to identify the problems associated with current climatic variability (droughts and floods) and move to address responses to these measures while considering the implications of longer-term climate changes and planning to address the impacts of these changes in a phased framework of actions and processes.

Since the National Development Strategy (NDS) seeks to address poverty alleviation and protection of the environment, it will be appropriate for adaptation measures to be considered as response measures under the NDS.

6.2 OBJECTIVES

The overall goals are the promotion of sustainable development and the reduction of vulnerability. Sustainable development will entail ensuring economic development of all the administrative regions, protection of the environment and equitable distribution of the wealth of the nation. Reduction of vulnerability will require minimizing the risks of the impacts, reducing economic losses and alleviating hardships while building the institutional response mechanisms for detecting and warning of the signals of the impacts and for responding to emergencies and other activities required to address vulnerable ecosystems.

6.3 CLIMATIC IMPACTS OF IMPORTANCE

The Vulnerability Assessment in Chapter 5 identifies the sectors, which are exposed to risk from climate change and its impacts. Adaptation should then address the vulnerable systems, activities and regions most likely to be in need of planned programmes of adaptation.

The major predicted impacts of global warming are:

- Higher temperatures
- High intensity rainfall
- Higher evaporation
- Water deficits
- Higher Sea levels
- Reduced crop yields
- Displacement of forest zones
- Saline Intrusion

These are expected to exacerbate an already "stressed" situation where:

- The coastal zone is affected by sea and estuarine defences being eroded by the sea.
- Human settlements are being established in low-lying areas.
- Health services are being continually upgraded to meet the demands of the local communities.
- Mining activities are changing the banks and bottom topography of rivers in the hinterland
- Droughts and floods affect parts of Guyana every year
- EL NIÑO / LA NIÑA affect several parts of the country, and
- Run-off effects of forestry resource utilization in watershed areas.

6.4 ADAPTATION AND ADAPTIVE CAPACITY

Adaptation to climate change in Guyana will to a large degree depend on the extent and magnitude of climate change impacts on the ability of physical and societal systems to cope with expected climate changes. Effective adaptation will largely depend on the resilience of these systems and the adaptive capacity of the people and Government of Guyana. The latter will involve available financial and technical skills and the experience of the Guyanese people and government. The process of adaptation is expected to be carried out by the government (including local government), the general population and communities of Guyana, both urban and rural.

The *resilience* of physical and human systems may be intrinsic or extrinsic in nature. Indicators of good or favourable resilience may include the presence of healthy, intact ecosystems, the ability of species to acclimatise to new temperature and rainfall regimes, the presence of land higher in elevation than the maximum predicted sea level rise. They also include storm surges, high productivity, reproduction and recruitment of species and high rates of natural recovery.

Intrinsic resilience, or homeostasis, refers to the innate ability of natural systems to maintain their integrity when subject to disturbances of some kind. For most natural systems, their natural immunity to climate change and sea-level rise is not clearly known. Hence, predicting which ecological variables (e.g. species, processes) might be affected by climate change and what effect this would have on ecosystem diversity, function and future resilience may be difficult.

Extrinsic resilience, on the other hand, refers to the ability of ecosystems to continue to maintain their integrity after having suffered the adverse effects from the same or other impacts. It is likely that the greater the number and intensity of hazards which have impacted on a system in the past, the greater its level of vulnerability to future stresses is likely to be. Because neither the natural resilience nor the altered resilience of any ecosystem is known, let alone the resilience which might arise as a result of integrated or interactive effects, it is difficult to directly estimate extrinsic vulnerability.

The present ecological integrity or level of degradation of ecosystems may be used as a gauge for their extrinsic resilience: the more degraded the ecosystem, as a result of past natural and anthropogenic impacts, the more vulnerable it is likely to be to future adverse environmental impacts, such as climate change and sea level rise.

6.5 THE ADAPTATION OPTIONS

Depending on the level of vulnerability and the region that is affected, the adaptation mechanism may not be the same. However, the vulnerability assessment reveals that adaptive responses will be required to cope with the impacts of climate change especially on the coastal zone. It is therefore necessary to firstly ensure that the capacity to detect, plan and respond exist in all relevant sectors. Hence, a necessity is that capacity building be a priority activity to be addressed at all levels of government and in the sectors.

An important aspect for realizing the necessity for adaptation is to incorporate its options to other sectoral and national policies, such as economic development policy, disaster prevention and management, and environmental management plans. Guyana already has immediate and pressing concerns, and climate change should therefore be considered in the national agenda since it will certainly impede socio-economic progress. Given the long lead-time for implementing adaptation, it is important to incorporate it with the other issues, in particular to the framework of sustainable development and integrated coastal zone management.

6.5.1 Capacity Building

The governmental capacity to deal with climate-related issues needs to be strengthened. The local communities have limited knowledge of their vulnerability due to the effects of global warming. The business community has also not shown any concern even though some sections of the business community are aware of the problem.

6.0 ADAPTATION MEASURES

The uncertainties in the predictions and impacts may result in a resistance towards policy development and the development of the capacity to deal with future vulnerable situations. It must be noted that observations are removing some of these uncertainties. However, it is also a fact that, because of the many "stress" issues which have to be dealt with in the immediate future, climate change may not be seen as a problem which has to be planned for now. The consequences of floods and droughts are addressed after the effects have been observed.

6.5.1.1 Capacity to Detect Climate Change and its Impacts

The Authority for monitoring climate is the Hydrometeorological Service of the Ministry of Agriculture. It has a high vacancy level especially at the professional level and available funds are inadequate to address training, purchasing of equipment, recruit field technicians and maintenance of reliable continuous records. This Department requires human, financial, technical and technological resource building if it is to play the critical role of alerting the nation to changes (or variability) of climate and issuing warnings to the sectors that will be affected.

There is the need to have studies conducted into the past and current climates of Guyana and how the climate is expected to change in the future. The resources for these studies will have to be provided from external assistance since global and regional models will have to be accessed and professional and academic resources will be needed.

Monitoring of the impacts such as erosion, inundation, along with changes in pest abundance, health signals, changes in fisheries, rice and sugar yields will require that staffing in the various agencies, in and out of Government, be available, trained and be capable of detecting the impact signals.

6.5.1.2 Capacity to Plan for Adaptation to Climate Change

Based on current and future signals of the impacts of climate change, planning to respond will become essential if Guyanese are to act in a proactive or purposeful way, rather than in a reactive manner. Planning must be done at all levels of government and society and must involve all sections of the Guyanese population. The National Development Strategy (NDS) does not adequately address climate issues, however, sustainable development is included in the framework which could be modified to suit the circumstances.

6.5.1.3 Capacity to Respond to Adverse Impacts of Climate Change

In Guyana, responses are often reactive to climate-related problems. All agencies, including the Civil Defence Commission should be strengthened in order to respond effectively to combat losses due to floods/droughts. Hence, the disaster – preparedness agencies (at all levels of the Guyanese Community) including the military, NGOs and local communities need to be provided with the capacity to respond effectively to abrupt and prolonged adverse conditions. Linkages with the Hydrometeorological Service, the housing and water agencies and public assistance agencies must be reinforced, and efficient programmes be setup to deal with response measures.

With regard to agriculture, especially in the coastal zone, the banking and insurance sectors must be prepared to assist farmers when they suffer losses. Other related assistance program may be put in place to alleviate hardships resulting from the adverse impacts of climate change. Recognising that agriculture is the backbone of the country's economy, it will be necessary for the farmers to be assisted so that they adjust rapidly to the adverse effects.

6.6 ADAPTATION STRATEGY

The IPCC (1995) provides the following types of response strategies, which can be considered for Guyana. They are:

- PREVENTION OF LOSS: Taking precautionary actions to reduce the intensity of the hardship. A controlled programme of actions to protect sections of the coast, retreat from very vulnerable areas or accommodate the rise in sea level in some areas will be required.

- TOLERATING LOSS: Using crop types, which can minimize losses, and accepting short-term changes, which will not result in serious long-term losses.

- SPREADING OR SHARING LOSS: Take actions to distribute the burden of losses over a region rather than having the area, within the region, bear the full loss. National and/or regional relief measures can be effective here.

- CHANGING USE OR ACTIVITY: The main activity or activities in an area may have to change because it will no longer be viable to continue with it.

- CHANGING LOCATION: When an activity is very important to the country, it may be wise to move it to a more friendly location.

- RESTORATION: A damaged system can be restored to its original condition. An example here can be flooded housing schemes.

There can be no unique response strategy for a country as large as Guyana. Responses must be area or region-specific and must operate under certain national guiding policies. It therefore means that the vulnerability of an area or region will have to be identified and detailed in terms of intensity, extent and human and material losses. This can be initiated as pilot projects.

The Caribbean Planning for Adaptation to Climate Change (CPACC) project has identified three pilot sites for detailed vulnerability assessments. These sites are Georgetown (the capital city), Leguan (a rice growing island in the Essequibo River) and Onverwagt, West Coast, Berbice within the Mahaica-Mahaicony-Abary (M.M.A.) rice development scheme. The assessment is not expected to be exhaustive and will require further studies and project activities to deal with responses to the vulnerabilities. It is hoped that these shall be done in the Mainstreaming for Adaptation to Climate Change (MACC) in the Caribbean project that is expected to follow from the culmination of the CPACC project.

Given the large uncertainties in the climate change projections, there may be two main categories of adaptation strategy: low cost, no-regrets responses and high cost, reactive measures. For Guyana, with limited financial and technical capacity, a narrow resource base and low resilience, the implementation of a low cost, no-regrets adaptation would appear to be an appropriate approach to adopt. While this strategy acknowledges that there is uncertainty regarding climate change and its impacts, it however seeks to minimize exposure to future risks, that may be exacerbated by climate change and sea level rise.

6.7 CAPACITY STRENGTHENING

The IPCC Adaptation Strategy is a sound one and should be followed as Guyana moves to avoid losses and suffering due to impacts of climate change. However, it assumes that the capacity to take actions exists and is competent. As was mentioned earlier, responsible agencies are not sufficiently trained nor fully equipped to deal with the problems. The human resource is also scarce.

It is therefore a priority for an assessment of the capacity needs to be undertaken for government, non-government, energy, private, media and local communities sectors. The assessment should also focus on capacities to monitor, research, identify and analyze signals, to take response/reaction measures on a timely basis.

An Early Warning System (EWS) is necessary for Guyana to deal with the impacts of, and responses to climate change. The capability must include Geographical Information System (GIS) and remote sensing with focus on preparedness initiatives. The capacity building initiatives should include:

- Data collection, analysis and presentation of data for all sectors;
- Mathematical modeling of climate and climate change processes;
- Food policy, risk management and coping activities;
- Public awareness and alertness;
- Water conservation;
- Community programmes

6.8 ADAPTATION BY SECTORS

In view of the impacts and vulnerabilities discussed in the preceding chapter, this section focuses upon adaptation strategies that may be used to minimize the negative impacts of climate change and sea level rise in Guyana. The discussion is limited to the sectors that are of major socio-economic importance and that are deemed most vulnerable to the adverse effects of climate change and variability. For each of these sectors, adaptation options are examined with respect to the policies/programmes, which should be executed within the next five years (short term) or during the medium to long term. The priority actions are given in the programmes for the next five years.

6.8.1 Coastal Zone

Table 6.1: Coastal Zone Adaptation Options

ITEMS	SHORT TERM OPTIONS	MEDIUM TO LONG TERM OPTIONS
COASTAL INVENTORY	Inventorise the coastal assets in all regions facing the Atlantic Ocean	Make periodic assessment of changes in the coastal assets
THE MOST VULNERABLE AREAS IN IMPACT ZONE I and II	1) Fortification of sea and river defences in accordance with Sea Level Rise (S.L.R) scenarios. 2) Conduct a study into the effect of ocean currents and eddies on water accumulation off Guyana's coast 3) Identify most vulnerable areas and determine adaptation strategy. 4) Conduct ground water resource inventory.	1) Implement adaptation strategies in stages to be determined from studies conducted in the short term and from the coastal inventory, such as: • **Managed Retreat** - no development in susceptible areas - development conditionally phased out - population policy to relocate to the interior - accommodation • **Protection** - hard structural options - dikes, levees and floodwalls - seawalls, revetment and bulkheads - detached breakwaters - floodgates and tidal barriers - saltwater intrusion barriers - wetland restoration and creation

6.0 ADAPTATION MEASURES

		2) Take actions to restore damaged areas and assets.
INTEGRATED COASTAL ZONE MANAGEMENT PROGRAMME (ICZM)	1) Continue to develop the components of a comprehensive ICZM programme 2) Implement coastal zone monitoring and assessment programmes 3) Identify areas where policy decisions will have to be taken to accommodate, protect or retreat.	1) Set up an ICZM division within the EPA with full legislative linkages to relevant agencies in and out of government.

Based on the preceding chapter, it would appear that Guyana, especially the Coastal Plains where most of the population and economic activity are located, would be most vulnerable to the impacts of sea level rise. One of the major likely impacts of sea level rise in the coastal zone of Guyana would be the loss of coastal wetlands that serve as protective barrier to the inland coastal area.

Coastal land loss due to a combination of inundation and coastal erosion is projected to have widespread adverse consequences in the low-lying Coastal Plain of Guyana. Land loss from sea level rise especially in coastal locations is likely to be of a magnitude that can disrupt virtually all economic and social sectors in the country. Recent estimates indicate that with a 1 m sea level rise, up to 10 km^2 of land could be lost, just on account of inundation. This figure would increase more than threefold to 37 km^2 (14%) with storm surge superimposed on a 1m sea level rise scenario. Similarly, based on the Brunn rule, a retreat of up to 100 m is projected with a 1m elevation of sea level.

The elevation of mean sea level at Georgetown on the coastal plain of Guyana is 51.05 ft. (Georgetown Datum: GD). Furthermore, the mean elevation of the roadways on the coastal plain of Guyana is 55.0 ft GD. The elevation of the highest tide level recorded at Georgetown is 56.41 ft. GD and the elevation of the high spring tides is 55.31ft. GD. On the other hand, the elevation of the sea defences in the coastal plain of Guyana range from 62.0 to 64.5 ft. GD. These figures show how vulnerable the coastal plain of Guyana would be to rising sea levels, especially when accompanied by tidal surges.

Several options have been identified for reducing land loss due to sea level rise. Abandonment of developed areas inland of today's marginal wetlands could permit new wetlands to form inland. In some cases, it might be possible to enhance the ability of wetlands to accrete vertically by spraying sediment on them or as in the case of deltas, restoring the natural processes that would provide sediment to the wetlands. Finally, Guyana has managed to artificially protect itself from high water levels through the use of a network of sea defences and gravity-controlled locks and dykes and, in extreme cases, pumping stations. The widespread use of pumping stations will have to be considered since gravity outflow may become an inefficient drainage strategy.

One of the most serious considerations for low-lying coastal Guyana is whether it will have adequate potential to adapt on the coast to sea level rise or retreat. Guyana may have the option to pursue adaptation measures such as retreat to higher ground and even raising the level of the land since sand and other aggregates are abundantly available, costs and resources permitting. The use of building setbacks aimed at discouraging further developments in the vulnerable coastal area would also appear to have great practical utility.

In extreme circumstances, sea level rise and its associated consequences could trigger abandonment and significant coastal migration at great economic and social costs. A planned retreat seems to be required now since the coastal zone is being taxed with population and developmental stress. The responses to inundation then fall broadly into the categories of retreat and creating stronger and higher sea defences in all vulnerable areas to hold back the sea. Sea defences are today used extensively in the coastal plains of

Guyana. The flooding of unprotected areas below high tide level could be similarly constructed around other coastal areas at risk to sea level rise. In sparsely developed areas, however, the cost of sea wall construction might be greater than the value of the property being protected.

Moreover, even where sea walls prove to be cost-effective, the environmental implications of replacing natural shorelines with manmade structures would need to be considered.

Potential responses to coastal erosion deriving from sea level rise fall generally into three categories: construction of walls and other structures, the addition of sand to the beach, and abandonment. A number of structures other than seawalls can be used to decrease the ability of waves to cause erosion, including groins (jetties), rip-raps and breakwaters. Bulkheads are often used where waves are small.

A more popular form of erosion control has been the placement of sand onto a shore area through beach nourishment procedures. Although costs can exceed one million dollars (US) per km, it is often justified by the economic and recreational value of beaches.

Although shore protection is often cost-effective today, the favorable economics might change in the future. Current estimates place the cost of sea defenses in Guyana at $ 35,000.00 US per km. A more rapid rise in sea level would increase the costs of shore protection. A number of countries have adopted erosion policies that assume a retreat from the shore. Many countries are now requiring homes that can be moved to be set back from the shore by a distance equal to shoreline recession from 30 years of erosion, while high-rises must be set back 60 years. Other countries require people to demonstrate that new structures will not erode for 100 years.

Other jurisdictions discourage the construction of bulkheads and seawalls. In many undeveloped countries, small, relatively inexpensive houses are found very close to the shore. Because the value of these houses is less than the cost of protecting them, they must be moved as the shore erodes. An accelerated rise in sea level would speed this process of shoreline retreat.

In the short term then there is the need for anticipatory adaptation action in response to rising sea levels in Guyana. Where communities are likely to adapt to erosion, anticipation can be important. The cost and feasibility of moving a house back depend on design and decisions made when the house is built. The willingness of people to abandon properties depends in part on whether they bought land on the assumption that it would eventually erode away or had assumed that the government would protect it indefinitely. Less anticipation is necessary if the shore will be protected. Nevertheless, some advanced planning may be necessary for communities to know whether retreat or defending the shore would be most cost-effective.

In the medium term, adaptation to sea level rise in the coastal zone of Guyana may involve the further fortifying of sea defences and the introduction of legislation relating to set-back limits so as to reduce the vulnerability of the peoples and structures.

In the long term however, Guyana may have to choose between further fortifications of sea defences or a more drastic population policy whereby peoples and infrastructures will be moved inland, where even at 25 miles the land is at 74 ft above mean sea level (GD). Guyana's population is relatively small and land space in the hinterland is abundant, although soils are mainly sandy. However, the rich agricultural soils are found mainly in the low-lying coastal area.

These projections consider population and socio-economic and other changes only to a limited extent.

6.8.2 Agriculture and Fisheries

Table 6.2: Agriculture and Fisheries Adaptation Options

ITEMS	SHORT TERM OPTIONS	MEDIUM TO LONG TERM OPTIONS
Assessment of vulnerable agricultural areas in IMPACT ZONES I and II.	**Crop production and fisheries** 1) Identify areas where losses can be tolerated, spread or shared. 2) Promote changing use or activity in most vulnerable areas, if necessary. 3) Substitution of crops 4) Improvement in farm level management and productivity 5) Identify inland and interior areas for promotion of large-scale agriculture. 6) Assess the impacts of global warming and climate change on Guyana's agriculture and fisheries.	**Crop production and fisheries** 1) Promote aquaculture and large scale farming in inland and interior areas. 2) Continue to address policy directions on export markets, insurance, transfer of technologies, introduction of new species of crops and fishes (salt tolerant etc) into Guyana 3) Implement programmes to alleviate poverty among farming and fishing communities, by taking the effects of climate change into consideration. **Livestock** 1) Genetically altered animal species

Climate change and variability would very likely bring about more extreme weather conditions ranging from excessive rainfall and flooding to protracted droughts, both of which would have damaging effects on Guyanese agriculture.

In the short term, one strategy to cope with the resulting mismatch between crop requirements and the thermal resources available for growth would be the substitution of crop varieties with greater thermal requirements. However, other characteristics of the growing season may place constraints on the choice of substitutes. For example, moisture constraints due to high evapotranspiration rates would restrict potential plant growth during the dry season. Improvements in farm level management and farm productivity may also be a viable short-term option for coping with the adverse effects of climate change in agriculture. These adjustments can be of several types: -

- of crop variety (thermal and moisture requirements and shorter-maturing varieties),
- of soil management,
- of land allocation to increase cultivable area,
- of using new sources of water (recycling of wastewater),
- of harvesting efficiency and

- of purchases to supplement production (fertilizers and machinery).

In the medium to long term, in addition to the farm level adjustments in management and technology, a number of potential regional and national policy responses may also need to be changed. Changes of land use to optimize production may be instituted. Because different crops respond differently to changes of climate and to varying levels of fertilizer application under those climates, any attempt to maximize output of each crop while minimizing production costs is likely to identify quite different allocations of land to alternative crops under different climates.
The National Agriculture Research Institute (N.A.R.I) should spearhead scientific research in order to cope with the effects of floods and increased salinity. Genetic Engineering and Biotechnology are possibilities for improving flood tolerance in crops. Genetically engineered salinity tolerance can also be examined. Breeding and selection of crop varieties that can withstand short-term anoxic/hypoxic soil conditions are also important research activities in responding to impacts of climate change.

A Change of policy to maintain national food security while avoiding over-supply, in the long term, is a worthwhile alternative. The effect of price support policies in countries such as Guyana is to encourage home production often at prices well above that of the world market.

Policy changes to maintain equitable regional farm incomes may also be instituted in the medium and long term. Because of variations climate have differing degrees of effect in different regions, the present regional pattern of farm incomes is likely to alter. As a result, government policies designed to reduce regional discrepancies may need substantial revision in order to maintain a level of equitable support.

Changes of policies supporting farm inputs are also to be considered. Where national farm policies tend to encourage inputs such as fertilizers and improved drainage these can be modified to encourage new levels of input appropriate for the altered levels of agricultural potential. In addition, further support may be needed in traditional areas of agricultural extension such as land management (e.g., instituting new soil management practices to control erosion), water management (e.g., improving efficiency of water use and optimizing irrigation water use) and the introduction of hybrids and modern pest control methods (e.g., adopting drought-resistant crop varieties and cultivation practices including biological control of pests) so as to ensure sustainable agricultural development in the long term.

In the long term, adaptation options for the livestock sector of Guyana may also have to be devised. This may include acceptance and use of genetically altered animal species that may be able to withstand higher temperatures and water stress and digest more hardy grasses.

Changes in water temperature, salinity and levels deriving from climate change and sea level rise may very likely affect the fishing industry of Guyana, thereby requiring the introduction of various adaptation measures.

In the shot term, policy changes may be required to ensure the viability of the industry. These may include procuring markets for fish and shrimp farmers whose levels of production and profitability may be lesser, adjustments to fishing methods and varieties harvested and even increased insurance to farmers to ensure the survival of the industry. In the long term, promotion of aquaculture in the inland and interior locations can be pursued, while salt-tolerant fish species can be introduced in ponds located in the coastal regions.

6.8.3 Water Resources

Table 6.3: Water Resources Adaptation Options

SHORT TERM OPTIONS	MEDIUM TO LONG TERM OPTIONS
Domestic/Industry - water conservation (metering, time-runs, etc) - implement monitoring and inventory of water availability while continuing the development of new artesian wells **Agriculture** - better control and management of supply network - introduce scientific monitoring and management of irrigation waters **Energy** - monitor the water availability of existing reservoirs for detection of increased evaporation	**Domestic/Industry** - stricter water conservation techniques and management - rainwater collection - development of inland and interior conservancies **Agriculture and Fisheries** - stricter control and management of supply network - drainage re-use - artificial recharge of reservoirs from nearby rivers etc. - removing sediments and weeds from reservoirs for more storage capacity - low water use crops - high value per water use crops - salt-tolerant crops and fish species - relocation of fishing ponds **Energy** - keeping reservoirs at maximum storage to reduce evaporation effects - changing releases to match other water uses - taking plants off in low flow times

Because temperature is projected to rise by 1 to 4 ^{o}C in Guyana, evapo-transpiration rates will rise substantially, especially if the CO_2 concentration triples, as seen in the previous chapter, which when combined with anticipated changes in rainfall will lead to higher water deficits and hence reduce the availability of water resources for industrial, residential and agricultural use in low rainfall years. This will most likely result in conflicts among the different economic sectors such as agriculture, industry and services for scarce water supplies.

In the short term, adaptation to the adverse impacts of climate change in the water resources sector may involve a number of water conservation measures, including metering, the use of time runs where water supply may be staggered according to region or to sectors, the more efficient use of irrigation water using advanced irrigation scheduling methods and the rationing of water during extremely dry years.

As for the medium to long term, adaptation measures may include:

- Stricter water conservation techniques, collection of rainwater for potable and non-potable use in the domestic/commercial/industrial sector, and the development of conservancies and artesian wells in the inland/interior locations as a result of sea level rise and anticipated inland migration.
- For agriculture use, stricter control and management of supply network, artificial recharge of reservoirs from nearby rivers, removing sediments and weeds from reservoirs for more storage capacity and cultivate crops that are salt-tolerant so as to re-use drainage water, crops that use less water and crops that are commercially important and expensive.
- The relocation of fishing grounds and ponds, depending on the changes in water quality brought about by climate change and sea level rise, the introduction of more salt tolerant species and changes in consumer habits relating to acceptance of new species for local consumption.
- Keeping reservoirs at lower head to reduce evaporation at hydropower sites, changing releases to match other water uses and taking plants off in low flow times.

6.8.4 Energy

Table 6.4: Energy Adaptation Options

SHORT TERM OPTIONS	MEDIUM TO LONG TERM OPTIONS
Energy Conservation • ***Commercial/residential/ public buildings*** - conservation techniques: reduce lighting in buildings not in use • ***Machines/Equipment/Vehicles*** - purchase of fuel-efficient machines/equipment/vehicles - efficiency/maintenance of machines/equipment • ***Transportation*** - implementation of a more efficient transportation plan **Alternative energy sources** - hydropower (to be promoted especially micro-systems and mini-scales) - co-generation from use of bio-mass to be pursued in the sugar, rice and forestry industry	**Energy Conservation** • ***Commercial/residential/public buildings*** - energy conservation techniques continued - design and construct buildings to reduce the potential use of air conditioning from rising temperatures • ***Machines/Equipment/Vehicles*** - continue purchasing of fuel-efficient machines/equipment/vehicles - improvement in efficiency/maintenance of machines/equipment/vehicles • ***Transportation*** - use of a mass transit system **Alternative energy sources** - hydropower and biomass co-generation (continued), wind farms, solar/wind hybrid systems, ocean thermal, wave energy

Based on the analyses of the impacts and vulnerability chapter, it is evident that, on the one hand the demand for energy for various economic activities, including interior space cooling, may increase and on the other the supply of energy, as for instance hydro-electric generation potential, may decrease in response to climate change. These changes would be further amplified by changes in population and economic growth.

In order to respond to the adverse effects of climate change in the energy sector, adaptation measures in the short term may focus on:

- Energy conservation techniques practical in buildings (commercial/residential/public buildings) such as reducing lighting in and around buildings when not in use or when it serves no purpose.
- Purchasing fuel-efficient machines/equipment and efficient maintenance of same.
- Setting up and implementing a more efficient transportation plan.
- Continuing to set up micro-systems and mini-scales hydropower station in the interior locations in selected areas to be developed.
- Continuing to promote co-generation of energy from using biomass resources (rice husk, bagasse, sawmill waste, slash waste in forest etc) in the sugar, rice and forestry industry.

In the medium to long-term however, adaptation measures may focus on:

- Continuing to promote energy conservation measures/techniques in the different areas (buildings, machines/equipment) as indicated in the short term options.
- Design and construct buildings to reduce the potential use of air conditioning as a result of higher temperatures, thus save on energy e.g. ceiling insulation and glass that transmit less radiation are areas that reduce cooling loads.
- Transportation - use of a mass transit system in the cities and for linking centres of commercial activities.
- Alternative sources of cheaper and less-polluting forms of renewable and sustainable energy such as, further hydropower development and bio-mass co-generation, solar, wind, ocean thermal and wave energy.
- Reduce energy consumption for lighting by use of high efficient Energy Saving Lamps, etc.

6.8.5 Forestry and Land Use

Table 6.5: Forestry and Land Use Adaptation Options

SHORT TERM OPTIONS	MEDIUM TO LONG TERM OPTIONS
Forest Management Plan - continue the control of logging practices - forest fire protection to be pursued **Land Use** • ***Human Settlement and Industry*** - cleared forest (from mining/forestry activities) and parts of savannah regions to be utilized for human settlement/industry • Using the Impact and Vulnerability Assessment as a starting tool, continue to carry out detailed studies in the interior region on: - soil fertility, changes in temperature, rainfall, and other climatic variables, spatial shift in vegetation and species mix	**Forest Management Plan** - sustainable logging practices (reduced impact logging) to be continued - promote agro-forestry/reforestation/afforestation of commercially important species in areas likely to favour growth as a result of a shift in vegetation due to climate change **Land Use** • ***Human Settlement and Industry*** - continue to promote options identified for short term - from studies conducted in the short term, promote human settlement, industry and agriculture in selected regions of the interior region

6.0 ADAPTATION MEASURES

Climate change and sea level rise would also supposedly affect the forestry sector of Guyana. This is one of Guyana's key economic sectors and adaptation policies aimed at its sustainability will have to be implemented.

In the short term, adaptation measures may have to be focused on a redefined forest management plan, addressing such concerns as a forest fire protection plan and stricter control of logging practices, under the supposedly drier climate.

In the case of land use, in the short term, cleared forest (from mining/forestry activities) and parts of savannah regions to be utilised for human settlement instead of clearing more forest for this purpose in response to migration from the coast as a result of sea level rise. Also, using the Impact and Vulnerability Assessment as a starting tool, continue to carry out detailed studies in the interior region to reveal:

- soil fertility
- areas likely to be impacted from severe reduction in annual rainfall and the area/areas likely to receive less annual rainfall overall
- areas likely to be affected by high temperature increases, and the area/areas likely to receive overall high temperatures
- areas likely to be significantly affected by a reduction in bio-mass (shift in vegetation type)

Based on these studies, choices will be made for developmental work in the best region/area, in the medium to long term, in the field of agriculture, housing/industry in the interior region.

In the medium to long term, the forest management plan may have to be altered to accommodate sustainable logging practices under the perturbed climate. These will include well-planned logging practices that ensure regrowth of the forests, regular monitoring of forest species to detect changes in mix of species and appropriate remedial action and policy changes, such as dredging if water levels are too low, that will facilitate the riverine transport of logs.

In the event of major shifts of forest zones, as pointed out in the previous chapter, long-term policy changes may have to address such issues as structural adjustments and reallocation of resources and peoples within the Guyanese economy.

Some particular measures which can be taken to protect the forests and prevent adverse land use changes, in the medium to long term are:

- Planned measures or activities to protect primary forest areas that are in particularly acute danger of destruction, and which can be accelerated, expanded or continued by the immediate provision of funds. Priority should be attached to speeding up the identification of areas in need of protection.
- Large-scale agro-forestry projects, especially in areas in which the forests are being threatened by shifting cultivation, burning, etc. as a consequence of growing populations. In addition, utilization of already farmed areas should be intensified in order to increase yields without having clear additional land.
- Establishment of fuelwood and timber plantation and environmentally friendly sources of energy, so that the energy and wood requirements can be met without having to exploit the natural forests of the tropics.
- Restocking of deforested land and rehabilitation of derelict areas to permit their use by agriculture.
- Promote human settlement and suitable industries in the interior regions most likely to have less annual rainfall but conducive temperature (leaving potential areas that will have high annual rainfall and soil fertility so as to promote agriculture, in the medium to long term), areas likely to have a reduction of bio-mass as a result of changes in vegetation type i.e. forest areas changing to savannah (leaving potential areas that will have high bio-mass density as a medium for carbon storage and continued benefits from sustainable logging). The Impact and Vulnerability Assessment already done can be used as a starting tool for identification of areas, but much detailed studies is needed.
- Integrated development measures, including promotion of trade and commerce and creation of jobs, outsides of tropical forest areas.
- Establish more protected areas for specie or biodiversity preservation.

- Practise sustainable-yield management.
- Carry out afforestation and restocking measures to ensure long-term emergence of new secondary forests.
- Safeguard the cultural identity and habitats of the indigenous population groups.

6.8.6 Waste

Insofar as the waste sector is concerned, climate change may exacerbate the very poor condition of waste management in Guyana, due to population growth etc. Currently there are a number of unmanaged dumpsites that, apart from being aesthetic eyesores, pose severe health problems, especially in the urban areas. Local municipalities are grappling with this problem along with assistance from other sectors.

In the short term then, adaptation measures should focus on improved waste disposal management plans, including the creation of more managed waste sites, especially in urban areas, and the implementation of waste reduction measures, namely reducing consumption and recycling and reusing products.
In the medium and long term however, waste management plans should also include sewage treatment and wastewater recycling that is not only beneficial to human health, but may also be linked to adaptation measures in the water resources and agriculture sectors.

6.9 CONCLUSION

It is evident then, that Guyana may be very susceptible to the adverse effects of climate change, especially of sea level rise. Key sectors of its economy including agriculture and forestry may need to respond to the adverse effects of climate change. The coastal zone of Guyana, where most of the people live and where most of the economic activity is concentrated would be extremely vulnerable to sea level rise. Proactive and purposeful adaptation strategies, with short and long term planning horizons, and on a sectoral basis, would be required to reduce the adverse impacts of climate change and sea level rise. Capacity building is seen as crucial to adaptation. The country must maintain the capacity to detect, plan and respond to the adverse impacts.

7.0 MITIGATION ANALYSIS

CHAPTER SEVEN

MITIGATION ANALYSIS

Guyana, as a Party to the UNFCCC, has a responsibility also to take actions to mitigate Climate Change by striving to reduce emissions of Greenhouse Gas and promote removals by "conservation and enhancement, as appropriate, of sinks and reservoirs of greenhouse gases" UNFCCC.

The strategies highlighted here have been prioritized in terms of short term, medium term and long term and concentrate on policy and technology options that will require external funding, technological and capacity building assistance.

An aerial view of a section of Guyana's rainforest

7.0 MITIGATION ANALYSIS

7.1 INTRODUCTION

It has been recognized during the past decade that increasing concentrations of greenhouse gases (GHG) in the atmosphere may lead to climate change and attendant environmental impacts, most of them adverse for countries like Guyana. Hence, various efficiency improvements and technological efforts have been directed towards identifying suitable Greenhouse gas mitigation (GHGM) options aimed at reducing emissions, notably of carbon dioxide (CO_2).

Mitigation analysis involves the development of programs related to sustainable development in the context of Climate Change and to the development of methodologies for assessing mitigation measures and of policy options for implementing adaptation/mitigation alternatives that shall allow Guyana to abate the increase in GHG emissions and to enhance their removal by sinks.

As was seen in the GHG Inventory chapter, the major economic sectors that contribute to GHG emissions in Guyana are the Energy sector, mainly in CO_2 emissions through energy use and transportation, and the Agriculture and Waste sectors, which contribute mainly to CH_4 emissions. As for GHG removals; the Forestry sector is the major sink for CO_2.

7.1.1 Macro-economic Impacts of Response Measures

With respect to macro-scale impacts of adaptation response measures (specifically to cope with the direct and indirect effects of climatic change on the living conditions, economy and society of Guyana), it should be noted that many of the measures have been proposed as being important components of a national development strategy regardless of climatic change. This is particularly the case of the proposed actions to reinforce the sea defences against changes in sea level. As was pointed out in previous chapters, the coastal area is already a crucial component of Guyana's economy and society. Permanent sea defences were not built throughout the coast and those in place need routine maintenance.

With respect to mitigation response strategies (reduction of greenhouse gas emissions), many actions suggested can also be justified in relation to other desired effects. Supporting such project/investment is not only necessary for coping with climatic change effects but can result in acquiring funding internationally.

Assessing the macro-economic impacts of the response strategies for Guyana's economy is beyond the scope of the National Communication because the detailed evaluation economic costs and benefits involved depend upon strategic decisions to be taken in the various sectors. However, the potential effects of mitigation and the costs and benefits of adaptation measures are provided as follows:

1. The impacts of mitigation measures must be seen against the backdrop of change (generally growth) in GDP. Will mitigation measures stifle economic growth? The answer clearly is that the mitigation measures must be achieved within the context of the National Development Strategy (NDS) especially as it relates to transfer of technology, industrial development and efficiency in the energy and industry sectors.

2. In an eventual detailed assessment of macro-economic costs and benefits, it would be important to distinguish between short and long term impacts.

   Short term impacts of mitigation measures, and also some adaptation measures (e.g. reinforcing sea defences), involve significant investment. Two points can be made:

- Investment in such mitigation and adaptation measures in the short term will generally generate positive impacts on employment (direct and through multiplier effects), income, taxes and consumption.

- The extent of these results can be expected to vary according to the degree to which such investment is funded from external (international) sources and the conditions under which the funding is provided. Direct external contributions would have little or no negative impact because the investment would not be taking away from current consumption in Guyana, except for any re-allocation of resources (e.g. public sector staff) necessary to manage such investment and projects.

Some points can also be noted about long term impacts:

- Long term strategies for mitigation may dampen economic growth slightly, but this is likely to have little negative impact. Notwithstanding, some long term strategies may however be positive; this would be the case if the measures were also an investment in the country's development, e.g. the refurbishing of sea defences.

- Furthermore, this investment can be seen as protecting the country's productive potential. It can therefore contribute to maintaining and enhancing economic growth and development.

- Generally, the measures involving investment in human resources and institutional capability should also be seen as having substantial positive effects for the country. Such efforts, while entailing training and set-up costs, will also have positive effects of building resilience and flexibility into the country's management. While some of this is specific to climatic change (e.g. monitoring equipment), a good deal of effort in the long term would have a positive effect on human resource capability generally.

In any detailed assessment of the macro-economic impacts of mitigation measures, it would be important therefore to:

- Define short and long term costs and benefits in relation to employment level, taxes, income and investment.

- Take into account the effects of investment according to source (internal or external) on the economy.

- Take into account the growth and development scenarios developed under the National Development Strategy (NDS) to use as a yardstick in measuring these macro-economic impacts

- Take into account the overall effects of the mitigation and adaptation measures on the resilience and adaptability of the country's economy and society, and

- Build up the analysis of overall impacts from sector by sector analysis.

In conclusion, it appears essential to view the chosen mitigation and adaptation strategies as a multi-purpose investment in the future of the country's economy and society. These strategies would therefore become even more compelling and such a perspective would facilitate the leveraging of the necessary investment funds to undertake the work.

7.2 MITIGATION OPTIONS/STRATEGIES

GHG emissions reductions for Guyana can be assessed by examining an extensive array of technologies and policy measures that accelerate technology development and use, diffusion and transfer in all sectors.

Enhanced GHG removals by sinks in the Guyanese context may include efficient land management and use, and measures aimed at conserving and sequestering carbon in the forestry and agriculture sectors.

In the following sections, several mitigation strategies applicable for each sector are described. This should give the Guyana Government a working list from which to base their eventual program of reduction and control of GHG. The mitigation strategies described are based on best practicable technology currently in use in other jurisdictions so it should not be difficult for Guyana to receive assistance to implement some of these options.

Table 7.1 presents a priority listing of short, medium and long term technology-based mitigation strategies for Guyana on a sector-by-sector basis. Table 7.2 presents a listing of viable policy options that the government of Guyana may use to mitigate its emissions of GHG.

7.0 MITIGATION ANALYSIS

Table 7.1: Priority listing of Mitigation Strategies based on Technology Alternatives for Guyana

Sectors	Short Term (2000-2005)	Medium Term (2006-2020)	Long Term (2021 and Beyond)
Energy	• Modernization of power plants - energy efficient - retro-fitting - decarbonisation - distribution efficiency • hydropower	• Less carbon-intensive fuels • Switching to renewable energy • wind farms, solar systems	• Continue to promote renewables
Transportation	• Efficiency improvement - less carbon-emitting fuels - tyre and lubricants • Pollution devices - catalytic converters • Import restrictions	• Alternative energy - diesel, natural gas • More efficient engines - 4-stroke - electronic systems	• Modern hybrid vehicles • Traffic and fleet management systems • modal shifts - rail in the interior
Buildings	• Reducing energy use - energy-efficient cooling systems - more efficient lighting, cooking appliances - updating building codes	• Thermal integrity - Cooling losses • Regulations - energy conservation labels	• Choice of materials - wood instead of concrete
Agriculture	• CH_4 - rice cultivation - forage quality - cooking fuels • N_2O - controlled fertilizers - nitrification inhibitors - solution of fertilizers	• CH_4 - hybrids - upland rice • N_2O - less use of undesirable fertilizers	• CH_4 - hybrids - new crops • N_2O - reclamation of abandoned lands - carbon sequestration
Land Use and Forestry	• Carbon conservation - control deforestation - harvest regimes - control fires and pests	• Carbon sequestration - forest area and density - carbon storage in soils and wood products	• Carbon sequestration - forest area and density - carbon substitution/use of wood products
Waste	• Source reduction - recycling - composting - incineration	• Source reduction/conservation - recycling - composting - incineration	• Recovery of CH_4 - downstream use

Table 7.2: Priority listing of Mitigation Strategies based on Policy Instruments for Guyana

Sectors	Short Term (2000-2005)	Medium Term (2006-2020)	Long Term (2021 and Beyond)
Energy	• Energy conservation - sensitization - transmission losses • Demand side management - pricing - competition - subsidies	• Facilitate less carbon-intensive technologies - accelerated depreciation - agreements on more efficient equipment • Development of comprehensive energy plan for the whole of Guyana	• Regulatory programs • Market pull and demonstration - development/ application of efficient technologies • Implementation of energy plan
Transportation	• Legislation - speed limiters - reduction of vehicle use - car pooling	• Government incentives - licensing : energy efficient vehicles - pricing: alternative fuel use	• RD & D: vehicle transport system technology
Buildings	• Regulation - mandatory energy efficiency standards • Voluntary Measures - builders/ manufacturers	• Market-based programs - incentives: energy-efficient products • Procurement programs - large purchases of energy - efficient products	• RD & D: - new energy - efficient building materials and products
Agriculture	• CH_4 - agricultural reform • N_2O - market-based programs - regulatory measures	• CH_4 - agricultural reform • N_2O - voluntary agreements - import restrictions	• CH_4 - modernization • N_2O - voluntary agreements - international support
Land Use and Forestry	• Regulatory measures - slow deforestation - reforestation	• Regulatory measures - monitoring - forest management	• Policy incentives - substitution
Waste	• Regulatory - legislation/institutional capacity - imports control	• Voluntary agreements • Incentives	• Technical assistance • Institutional strengthening

7.2.1 Energy Sector

Energy Production and Consumption

Energy Industries/Industry

Guyana derives the bulk (> 90 %) of its power supply from the generation of electricity by thermal power plants fed by carbon-rich liquid fossil fuels (See Chapter 4).

Several Greenhouse Gas Mitigation (GHGM) technology-based options have been proposed for reducing GHG emissions in the energy sector (See Table 7.1). For instance, some of the short-term options for mitigating CO_2, the most important GHG, in the energy sector includes: the modernization of existing power plants through the use of energy efficient technologies for new power plants or retro-fitting existing plants with modern efficient technologies such as decarbonisation of flue gases and fuel.

In the medium term, mitigation options for Guyana may include the use of less carbon-intensive fuels, such as switching from liquid fossil fuels to natural gas or simply the use of cleaner liquid fuels where costs can be justified. The greater use of renewable energy technologies for power generation such as solar and wind energy, which may not be cost-effective in the short-term because of the technology limitations and hydro power, for which Guyana has a huge potential, are viable short and medium-term mitigation options for Guyana. In the longer term mitigation options may include wind farms and wind/solar thermal generating systems for regional development.

The oil-fired power plants in Guyana are probably the largest sources of GHG emissions. A viable mitigation option would be the phasing out of existing power plants and replacing them by new, natural gas fired power stations (medium term strategy). The existing power plants can certainly be optimized for more efficient fuel use by simply implementing a regime of preventative maintenance. However, trying to switch these power plants to cleaner burning fuels (diesel as opposed to fuel oils) is expensive and not cost-effective in the context of the age of the plants. The benefits of these two strategies would be realized in reduced fuel costs, reduced equipment repair costs and a stabilization of electricity costs to the consumer. One other action, which will have to be addressed, probably in the short term, is making the transmission/distribution system more efficient.

As for the policy options that the government of Guyana may choose to use in the short term to mitigate CO_2 emissions in the energy sector, these are: the use of demand side management options that focus on pricing, competition and government subsidies to ensure a preference for cleaner fuels (See Table 7.2).

Another viable short-term policy alternative would involve modified energy consumption patterns through the use of pricing strategies and the sensitization of the public to energy conservation, and the reduction of transmission and distribution losses through system optimization techniques including the integrated operation of grid networks.

In the medium term, the government of Guyana may choose measures that facilitate the penetration of less carbon-intensive technologies, such as provisions for accelerated depreciation of new equipment and negotiated agreements with industry that favour the use of modern and more efficient equipment.

Alternatively, in the long term, the government of Guyana may choose to use utility demand-side management programs and regulatory programs and market pull and demonstration programs that stimulate the development and application of advanced and efficient power-generating technologies.

Other long-term policy options that the government of Guyana may adopt include government regulatory measures, voluntary agreements with the power generating utilities and infra-structural measures aimed at removing institutional barriers and the development of a comprehensive and efficient energy system planning. One long-term option is the purchase of power from a neighbouring country.

7.0 MITIGATION ANALYSIS

Transportation

The transportation sub-sector is another sector where significant gains in GHGM can be achieved in Guyana. In 1994, this sector consumed 19 % of all the liquid fossil fuels imported into Guyana.

Some of the more viable technology-based measures that may be used to reduce GHG emissions in the transportation sector of Guyana in the short term may include: energy use efficiency improvements through the use of less carbon emitting fuels such as natural gas, improvements in tyre performance and lubricants and other accessories such as transmission improvements and the use of lighter vehicles, especially for urban use. Other short-term options may include the mandatory installation of pollution removal devices such as catalytic converters in vehicular exhaust emission systems and the implementation of tougher legislation relating to exhaust emissions (See Table 7.1).

Another feasible policy directive applicable to the transportation sector in the short term is the restriction of the importation of foreign used vehicles to cars that are a maximum of five (5) years old and to heavy vehicles that are a maximum of three (3) years old. This will provide much needed control to the increasing population of older vehicles on the roadways of Guyana. Ideally, the first approach to controlling or reducing CO_2 emissions from tail pipes is to restrict the age of the vehicles on the roads to those that may meet better emission standards. Consequent with this approach, will be the reduction in consumption of fuel, since older cars use more fuel per mile than new cars.

In the medium term, the use of alternative energy sources, for instance switching to diesel from gasoline, although this may increase emissions of NO_x and particulates, and even to LPG and CNG. Alternatively, the greater use of more efficient and less-polluting engines, such as conversion from 2-stroke to 4-stroke engines and greater use of electronic engine systems may be other medium-term mitigation options.

In the long term, when hybrid vehicles technologies are sufficiently improved, costs permitting, this may be a very attractive CO_2 mitigation alternative. Also, infrastructure and system changes, including greater use of and reliance on traffic and fleet management systems and modal shifts from road to rail transportation systems, in the interior of Guyana, may also be instituted as a long-term GHGM option.

As for the policy instruments that may be used by the Guyanese government to mitigate GHG emissions in the transportation sector in the short term, the alternatives are, among others: legislation of fuel economy standards, including compulsory fitting of speed limiters, the use of light-duty road vehicles in urban traffic and heavy-duty vehicles for freight traffic (See Table 7.2).

In the medium term the government of Guyana may choose to use incentives, through licensing fees for instance, to encourage the purchase of energy efficient vehicles.

Another measure may be the use of government incentives, such as price control to encourage the use of alternative fuels, such as natural gas or bio-fuels that are less polluting.

As for the long term, mitigation policies may be geared at government sponsored RD & D aimed at vehicle transport system technology.

Residential, Commercial and Institutional Buildings

Buildings are responsible for a significant amount of carbon emissions. Guyana can therefore also target this sector to reduce its GHG emissions. There are several easily attainable short and medium term technological options for reducing GHG emissions from buildings (See Table 7.1). This would involve greater deployment and use of technologies aimed at reducing energy use by building equipment and office appliances, including energy-efficient cooling systems such as electric air source cooling pumps, greater use of more efficient lighting systems and cooking appliances aimed at reducing energy consumption such as compact fluorescent lamps and lighting control systems.

In the medium term, mitigation options in the buildings sector may include the regulatory enforcement of energy conservation labels on equipment and appliances. Improvements in buildings thermal integrity aimed at reducing cooling energy losses may also be used to advantage.

In the long-term mitigation technological options to reduce GHG emissions from the buildings sector of Guyana may focus on the use of more energy efficient and less environmentally harmful building materials. For instance, high quality durable wood such as green-heart and purple-heart, with which Guyana is well supplied and which has a much higher thermal retention capacity than brick or concrete, not to mention the lesser energy use in the production of wood as opposed to brick or concrete and the carbon sequestration potential of wood, may prove to be an attractive building material alternative.

There are several policy instruments that Guyana may use, preferably in combination to encourage practices that would reduce GHG emissions in the residential, commercial and institutional sectors (See Table 7.2).

At first, in the short term, the Government of Guyana may enact regulatory measures relating to mandatory energy-efficiency standards. The government should also facilitate these measures, including defining these standards and ensuring their cost effectiveness. Voluntary standards and measures, as a good will gesture on the part of manufacturers and builders, would greatly help to make these policies more effective.

In the medium term however, market-based programs that would provide incentives to promote increased use of energy-efficient technologies and practices may also be an attractive policy option for Guyana. For instance, utility demand side management that would provide incentives for the purchase of energy-efficient products and manufacturer incentive programs that would reward companies for the development and commercialization of high-efficiency low-energy-use products may be implemented.

Other medium-term policy alternatives that the government of Guyana may use would include procurement programs, where large purchases may make the acquisition of energy-efficient products affordable and the adoption of cost-effective energy efficiency measures in exchange for technical support and marketing assistance.

Finally, in the long term, government and large industries can encourage RD & D programs, such as the development and use of low emissive windows and high-efficiency air conditioners and refrigerator compressors.

7.2.2 Industrial Processes Sector

GHG emissions in the Industrial Processes sector relate to exclusively NMVOC emissions from the various food and beverages production processes, among others. In 1994, emissions of NMVOC totaled 16 Gg from this sector. GHG abatement in this sector is not viewed as an area where mitigation efforts can be pursued for Guyana.

7.2.3 Agriculture Sector

GHG abatement in agriculture will most certainly promote and enhance sustainable agricultural production, which will benefit the farming community and make agricultural products more acceptable to consumers. Several technological alternatives are available to the government of Guyana for mitigating the important GHG's in agriculture.

Mitigation of CH_4 Emissions

CH_4 emissions in the agriculture sector of Guyana are mainly attributable to the cultivation of rice under flooded anaerobic conditions, to enteric fermentation of animals and burning of biomass (refer to chapter 4.0 or summary tables for emission estimates).

7.0 MITIGATION ANALYSIS

There are a variety of technologies that may be used to mitigate CH_4 emissions from agriculture in Guyana in the short and medium term.

For rice cultivation, modified water regimes involving lesser water requirements and energy demand for short critical periods, without compromising yields, may be used. Other studies elsewhere in the Caribbean have found that maximum water levels in rice paddies may be reduced from 200 to 50 mm and minimum water levels from 150 to 25 mm, without significantly affecting rice yields.

Other shifts in cultivation techniques, such as the use of mineral as opposed to organic fertilizers, have been shown to result in higher yields while at the same time reducing CH_4 emissions. Alternatively, direct seeding of rice fields, which is more amenable to mechanization, albeit energy dependent causes less disturbance to the soil and reduces CH_4 emissions, while at the same time moving up the harvest season to two to four weeks earlier.

In the medium and long term, CH_4 mitigation in agriculture may be achieved through the development and use of hybrids, requiring less water and energy, which may well be required in response to the impacts of climate change and the expansion of upland rice acreages, that also require less water and energy, provided that yields are not substantially affected. Also, the introduction of new or other crops that emit less CH_4, provided that they are economically feasible, may also be considered as a further mitigation option.

CH_4 emissions from enteric fermentation in animals on the other hand, may be somewhat reduced in the short and medium term by upgrading low quality forages that produce high CH_4 emissions as a result of switching to rumen-resistant starches such as maize and sorghum, that cause less CH_4 emissions. However, this option may be limited by higher costs, more fertilizer use and hence soil and water pollution, and even by resistance based on dietary and social customs.

The various CH_4 mitigation options described above would have to be guided by different policy instruments that focus on agricultural reform and modernization.

In the short and medium term, such reforms may include the implementation and use of extension expertise, sensitization of farmers to the benefits of the reforms and government incentives aimed at ensuring the adoption of the policy changes being proposed.

In the medium and long term, on the other hand, the focus of government policy may shift towards modernization of agriculture in Guyana, focusing on the introduction of varieties and crops and cultivation methods that produce less CH_4 emissions costs and societal acceptance permitting.

Mitigation of N_2O Emissions

The primary sources of N_2O emissions from agriculture in Guyana are the use of mineral fertilizers, the cropping of nitrogen-rich legumes, animal waste and biomass burning.

The technology options that may be used to mitigate N_2O emissions in the short term would include the use of controlled release fertilizers and nitrification inhibitors and the integration of nitrogen application with farm water management, such as irrigation application.

In the medium and long term, technology alternatives may focus on the use of less N_2O-emitting fertilizers on the one hand and on indirectly increasing the N_2O sink capacity of agricultural lands on the other through reclamation and reforestation of abandoned agricultural lands and increasing the GHG sequestration of agricultural soils.

Policy instruments that may be used to mitigate GHG emissions in the agriculture sector of Guyana in the short term may be classified as, firstly market based programs, focusing on the reform and reduction of agricultural support policies and on tax disincentives aimed at limiting the use of nitrogen fertilizers, except for paddy rice cultivation. Secondly, regulatory measures aimed at limiting the use of nitrogen fertilizers for sugarcane and vegetable crops.

Other short and medium term mitigation options may include the use of a negative import list to control the importation of undesirable fertilizers. Also, policy directives to reforest abandoned agricultural lands may also be considered as a viable medium term mitigation strategy of increasing GHG sink capacity.

In the long term, policy options may shift to voluntary agreements regarding soil management practices that would enhance carbon sequestration.

7.2.4 Land Use and Forestry Sector

Forests act mainly as a sink for atmospheric CO_2 through carbon absorption and assimilation in the photosynthesis process. However, forests also emit CO_2 through excess carbon ejection in the respiration process and more importantly through the decomposition and burning of woody biomass.

Guyana's forests act as a tremendous reserve for the storage of carbon in live and dead vegetation and in forest soils. Mitigation of net GHG emissions from forests and forest soils should therefore be focused on methods aimed at enhancing carbon uptake. Therefore, steps must be taken to ensure that Guyana's forest protection plans do not turn out to be merely new versions of the country's forestry action plan.

Accordingly, the national tropical forest protection plans must be aimed at:

- Emphasising sustainable use of tropical forest resources.
- Ensuring the participation of local population and indigenous societies in the development of national tropical forest protection plans.
- Promoting reforestation measures.
- Exclusively implementing sustained yield management methods.

In the short and medium term, technologies that may be adopted for reducing net GHG emissions in the Land Use and Forestry sector of Guyana may include management for carbon conservation aimed at controlling deforestation and harvesting regimes through systematic monitoring, protecting forest reserves by controlling fires and pest outbreaks. Policy should also oblige concessionaires to provide in forest management plans, a component, which includes mitigation measures to enhance sinks as well as reducing emissions.

In the medium and long term, technology options may be management for carbon sequestration and storage by expanding the area of forest ecosystems and the density of forest biomass and increasing the carbon absorption capacity of forest soils and the storage of carbon in durable wood products. Also, management for carbon substitution through increasing the transfer of forest biomass into durable products rather than using fossil-fuel based energy products, such as cement-based and other non-wood building materials.

In so far as policy measures for reducing net GHG emissions in the Land Use and Forestry sector of Guyana are concerned, there are several options. Amongst these, in the short and medium term, are regulatory policy measures aimed at slowing deforestation, promoting forest regeneration and increasing the amount of carbon stored in forests by actively promoting reforestation and afforestation programs.

In the medium and long term, policy options may focus on incentives aimed at promoting substitution management whereby renewable forest carbon biomass is transferred into products that substitute for or reduce the use of fossil fuels, such as the use of bio-fuels for power generation in the energy and transportation sectors, though cost considerations may act as an impediment. Also, the lumber industry should be regulated by the EIA framework, whereby climate change impacts and mitigation may be major components.

7.2.5 Waste Sector

The main GHG emissions deriving from the Waste sector emanate CH_4 emissions from solid waste disposal and N_2O emissions from human sewage.

The Waste sector is in dire need of upgrade in Guyana. Solid Waste handling and disposal should be the sector targeted for priority action both from an environmental perspective and as a means of controlling a significant CH_4 emission source. CH_4 emissions from uncontrolled dumpsites are 20 times greater than from a single engineered sanitary landfill of the same size.

Mitigation of CH_4 Emissions

Among the technical options that Guyana may choose to mitigate CH_4 emissions from solid waste disposal sites (SWDS) in the short term are firstly source reduction efforts whereby conservation and home-based garbage separation may be used to decrease the amount and types of garbage that turn up at SWDSs. This may be achieved through recycling of products such as paper, plastics bottles and metal cans, home-based composting and incineration. The problem with incineration however, may be the release of other air pollutants such as CO_2, which nonetheless has a lower global warming potential than CH_4.

The short and medium term technological options should focus on the installation of a combination of transfer stations and centralized sanitary landfills in each of the major population centers (Georgetown, Linden and New Amsterdam). Once this is done the medium-term strategies of waste segregation, waste recovery and waste recycling can be implemented.

7.3 SUMMARY AND CONCLUSIONS

It transpires from the above then, that Guyana should focus its GHGM efforts on: CO_2 emissions from the energy sector, CH_4 emissions from the agriculture sector and the preservation and strengthening of the CO_2 sink in the Land Use and Forestry sector. However, these mitigation efforts would call for resources, both technical and financial, that Guyana may not have. There would therefore be the need to actively solicit and pursue international funding agencies such as the Global Environment Facility and the World Bank.

The following projects may be identified as possible avenues to help Guyana reach its objectives insofar as GHGM is concerned.

1. The major contributor to GHG emissions in Guyana is the energy sector. In 1994, this sector emitted 1446 Gg of CO_2 where the energy industries sub-sector accounted for 602 Gg or 42% of emissions.

   In the short term then, Guyana should actively pursue measures aimed at retrofitting its existing power plants so as to reduce CO_2 emissions and trace gases from the energy industries sector.

   In the medium and long term, the development of alternative non-fossil and renewable energy sources may also be worthwhile. With its abundance of rivers and natural waterfalls Guyana has huge potentials for hydropower generation. Unfortunately, most of the potentially viable sites, such as at Moco-Moco, Tumatumari and Amaila, are located in the interior far from the coastal markets. If this sector is to be further developed projects related to transmission losses reduction or the development of new hydropower schemes closer to the Coastal Region may have to be targeted. Alternatively, projects related to the exploitation and use of other sources of non-fossil renewable energy, such as solar power and wind energy, costs permitting, in the Coastal Region may be evaluated.

2. Another major GHG in Guyana is CH_4 emissions from rice paddies. Guyana is an important producer of rice and it is one of the major contributors to GDP. In 1994, CH_4 emissions from rice paddies amounted to 22.33 Gg. Guyana may therefore choose to mitigate CH_4 emissions from its rice paddies by looking at hybrids or upland varieties that emit less CH_4. However, a pilot research project has to be

undertaken to ensure costs are not inflated and more importantly, quantity and quality of yields are not compromised.

CHAPTER EIGHT

FINANCIAL ASSISTANCE AND TECHNOLOGY TRANSFER

Solar Energy Technology

8.0 FINANCIAL ASSISTANCE AND TECHNOLOGY TRANSFER

8.1 RELEVANT CONVENTION ARTICLES

In carrying out the commitments under the Convention, Guyana recognizes the importance of actions which have to be taken by Guyana and by the developed Country Parties in order for the country to be able to implement mitigation and adaptation measures. The articles of relevance are:

- Article 4.1 (b) - Parties to undertake programmes to mitigate climate change and facilitate adequate adaptation to climate change.

- Article 4.1 (c) - Parties to cooperate in the transfer of technologies, practices and processes that control, reduce or prevent ghg emissions in all relevant sectors including energy, transport, industry, agriculture, forestry and waste management sectors.

- Article 4.5 - The developed Country Parties and other Annex II developed Parties shall promote, facilitate and finance the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties to enable them to implement the provisions of the Convention.

8.2 THE NEED FOR ASSISTANCE

Guyana has a highly developed low lying coastal area, several populated small islands, forested and savannah areas. It is a country susceptible to serious droughts, with regions having fragile ecosystems and its economy is highly dependent on income generated from the utilization of fossil fuels. It is a developing country, which has specific needs and special situations such as a vulnerable coastal plain where over 90% of the populations reside. Funding and transfer of technology are therefore required to address critical adaptation issues as well as mitigation programmes.

The capacity and institutional base of government (including local government),private sector, other NGOs, scientific and professional groups and communities are weak and will require assistance to build up the human, organizational, information assessment and monitoring capacity. These capacity building needs are addressed in the following sections.

8.2.1 Capacity Building Needs

Capacity building is required at all stages in the process of technology transfer. The Government of Guyana is committed to ensure that programmes are fully supported by the governmental agencies. However, the capacity in terms of human, organizational and information assessment is weak. While it is recognized that effective technology transfer requires efficient networking, the weak capacity prevents an advance towards effective communication of technologies and understanding of their usefulness in Guyana. It is therefore critical to address the building of capacity in the governmental and private sector institutions, while at the same time improving the networking of these institutions in order to effect efficient and useful sharing of information on technologies, demonstrated capabilities of technologies, etc.

8.2.1.1 Human Capacity

Technical, business and regulatory skills are very limited in Guyana. Capacity is required to assess, select, import, develop and adapt appropriate technologies. This can be tackled by formal training of local personnel; formation of links with other enterprises, trade, research and professional organizations; and through operational experiences with other firms.

It is the view that an initial technology needs assessment is required to be done. This assessment should examine the current capacities of institutions, private sector, professional and scientific organizations and local communities to deal with the issues and identify what needs are required to improve the situation.

The assessment should also examine the current technologies in use in Guyana in the various sectors with a view towards assessing the efficiency of the technology; the emissions associated with the technology and identify technologies which can prove to be more climate-friendly. It will be necessary for the assessment to include possible sources of financing or investment and make recommendations on the most effective measures to be taken to address Guyana's mitigation programmes.

Since the major part of Guyana's emissions of greenhouse gases come from the energy sector, special attention should be placed on improving the efficiency of current power generation and utilization, conservation practices and on use of fuel-efficient vehicles, equipment, etc. and on energy utilization in buildings. Agriculture and forestry are also sectors which can be involved not only in reducing emissions but also in enhancing sink mechanisms. Waste Management and Human Health will also have to be considered since improved technologies in these sectors will enhance Guyana's mitigation process, improve its health system, and allow for adaptation to the adverse impacts of climate change.

8.2.1.2 Organizational Capacity

The government, the private sector and the community institutions must together be involved in development and technology transfer. The need exists for strengthening the capacity of the various agencies as well as to improve the networks in which the several agencies can contribute to the transfer of technology. The needs include physical and communications infrastructure; opportunities to develop firms for management consulting, energy services; investment and product rating and law; encouraging cooperative engagement of all sectors and agencies in environmental policy-making and project formulation and the involvement of communities in decision-making where their needs are concerned.

8.2.1.3 Information Assessment and Monitoring Capacity

There is the need to ensure that information is available and can be competently assessed to take into consideration the strength/weakness of the underlying economics, adequacy of financial services and adaptation to local conditions. There is also the need to encourage groups of companies to build technology networks.

Government needs to establish a system of improved indicators and data collection on flows of environmentally sound technologies in addition to technology performance benchmarks compilation to indicate the potential for technological improvements. Establishing linkages to international and regional networks (inclusive of private sector networks) can be done by the setting up of a technology information centre with network links to NGOs, private sector, consumer associations, professional and scientific associations and consulting firms.

8.3 BARRIERS TO THE TRANSFER OF ENVIRONMENTALLY SOUND TECHNOLOGIES

The Government of Guyana has been addressing the matter of eliminating the barriers to trade and investment. The economy is generally a market-oriented one and there exists an open and transparent banking and trading system. Institutional corruption is also being addressed with a policy of “zero tolerance” to exposed corrupt public servants.

However, in Guyana, the most pressing obstacles are insufficient human and institutional capabilities; inadequate understanding of local needs, demands and potential for technological transfer; and the inability to access, assess, select, import, develop and adapt appropriate technologies.

The government sees the private sector as the engine for economic growth. However, the need exists for smaller firms to be able to access capital at concessionary lending rates and for the legal institutions to be supported to develop codes and standards for the evaluation of environmentally sound technologies. It is also recognized that the private sector will be slow to be involved in some types of coastal adaptation technologies (such as sea defence infrastructure) and that the government will have to take the lead role in the acquisition and utilization of these technologies.

There are several areas in which deficiencies can be barriers to technology transfer. Inadequate capacity to collect data, information and knowledge, especially "emerging" technologies; no confidence in unproven technologies; aversion to taking risks; inadequate science, engineering and technical knowledge available to the private sector; and insufficient research and development are some of the areas of concern. In order to fully address the matter of barriers to the transfer of Environmentally Sound Technologies (EST), five categories of barriers shall be considered.

8.3.1 Economic and Financial

Guyana is a developing country now emerging from a period of poor economic and social performance. The inadequate economic base and low incomes naturally lead to low levels of savings and investment. Development and transfer of ESTs is therefore not effective. Market barriers such as lack of incentives and, in a few cases, the existence of disincentives may not be attractive to the transfer of ESTs. A fair pricing system needs to be addressed for all areas in which ESTs can be introduced so that price signal can be relied on. The size of the markets in Guyana is also relatively small thereby posing a problem to business when the low rate of return on investments is considered. Guyanese businesses are also generally averse to risk-taking and local loan providers may not be amenable to assisting in what will be viewed as risky investments.

8.3.2 Organizational and Institutional

For many of the mitigation ESTs, a favourable business environment will have to be addressed. The one-stop shop mechanism, GOINVEST, which has been established to fast-track the governmental procedures for investment projects is a positive action taken by the government. However, the business environment requires transparent legal systems, strong enforcement mechanisms for laws relating to investments and companies, short arbitration processes, clearly defined property rights, reasonable legal fees, brisk institutional actions clearly defined macro-economic policies, adequate communication capability and availability of suitable firms for subcontracting.

8.3.3 Human Resources

There is a serious lack of relevant training in Guyana. Training in project development, management and operations need to be intensified so that advanced technology can be sought and utilized. The relatively low level of technological capability in Guyana presents a major barrier to the transfer and development of technology.

8.3.4 Technological

There is a weak institutional structure to support the development and implementation of appropriate technology standards and regulations. The capability of the Guyanese people to use and manage imported hardware is lacking in this regard and this diminishes our ability to alter, improve or retrofit foreign technologies for local adaptation or to eliminate problems without unnecessary and costly recourse to suppliers.

Normal engineering procedures for testing, commissioning, trouble-shooting and supporting imported equipment are either not in place or neglected. This can pose a serious problem with renewable energy technologies by contributing to poor performance.

8.3.5 Technology Information

8.0 FINANCIAL ASSISTANCE AND TECHNOLOGY TRANSFER

There is a poor technical information base in Guyana. Limited access to information affects the local capacity for effective identification and assessment of technologies. It is important to have access to international information and local data required for the design of investment projects. Performance data and banking and insurance information is needed for making decisions. Detailed information on indigenous technologies is also not available.

8.4 TECHNOLOGY NEEDS

Decision 4/CP.4 identifies several areas and sectors in which actions can be taken to implement Article 4.5 of the Convention. These are all relevant to Guyana's technology needs if the country is to comply with its commitments under the Convention. The needs are addressed under two categories: capacity building and sectoral considerations.

8.4.1 Capacity Building

- Strengthening the capacities and capabilities of government (including local government) and private sector agencies so that Guyana can contribute to the ultimate objective of the Convention and achieve sustainable development.
- Accessing support for capacity building and the strengthening of appropriate institutions in Guyana to enable the transfer of environmentally sound technologies and know-how.
- Providing assistance to Guyana in its efforts to build capacity and institutional frameworks to improve energy efficiency and utilization of renewable energies through multilateral and bilateral cooperative efforts.
- Providing assistance to Guyana to build capacity for sustainable management and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems.
- Providing assistance to Guyana to build capacity to adapt to the adverse effects of climate change.
- Providing assistance to Guyana to strengthen its endogenous capacities and capabilities in the areas of technological and socio-economic research and systematic observation relevant to climate change and its associated adverse effects.
- Cooperating in and promoting capacity building of Guyana at the international, regional, sub-regional and national levels through cooperation programmes supported by the United Nations and other multilateral agencies, as well as bilateral agencies.

8.4.2 Sectoral Considerations

8.4.2.1 Residential, Commercial and Institutional Building Sector

Energy is used in this sector to cool buildings, provide lighting and services such as cooking, computers, refrigerators, etc. Energy use efficiency and conservation in addition to the application of efficient technologies can be important. There is the need for assistance to Government to improve its capacity and strengthen its institutional capability to develop environmental standards for new buildings and equipment, information, education and labelling programmes and research, development and demonstration programmes. There is also the need to assist government and the private sector to work towards creating a market environment for the private sector to lead in the transfer of technology by decision-making on a wide range of financial and economic incentives, policies and regulations. A study is required also on how to encourage and develop community programmes by identifying needs at the level of the community and by taking into consideration the initiatives of the community.

8.4.2.2 Transport

Energy use in this sector is almost entirely dependent on fossil fuels. The costs of technical and non-technical options are affected by availability of source, technical know-how, institutional capacity and local markets. There is the need for assistance in preparing a comprehensive study into actions which the Government of Guyana can take to address the mitigation issue in this sector. The study must include consideration of improving the quality of imported fuels, alternative fuels (including methanol and ethanol) and energy use in the airline industry.

The public transport system needs to be studied with a view towards addressing energy savings; changing the transport infrastructure and systems to reduce travel trips and increase freight volume per trip; and, to explore ways and means for cooperation with other countries to effect technology transfer. Above all, there is the urgent need for the development of a policy statement and the building of capacity to receive technology inflows.

8.4.2.3 Industry

The use of new process schemes, energy and resource efficiency, materials substitution, changes in design and manufacture of products leading to less use of material and increased recycling are all needed in the industrial sector. There is the need to know what are the technologies that are available for each type of industry and to obtain the investments needed to acquire them. Capacity building of the relevant agencies will be necessary for accessing, assessing and seeking financial assistance.

8.4.2.4 Energy Supply

Economic development and international competitiveness depends on reliable and reasonably priced energy supply. Guyana depends primarily on fossil fuel imports but the potential for using renewable sources of energy exists. It is clear that, in this sector, significant investments will be required for transfer of technology. Therefore, the role of the Government is important to facilitate technology transfer.

An energy sector policy has been developed and can be used to encourage and facilitate technology transfer in the fossil fuel sector to foster clean energy technologies, switching to lower carbon fuels and high efficiency power generation.

The greatest potential for Guyana to mitigate greenhouse gas emissions lie in the use of renewable energy sources. However, lack of investments and the high capital costs have been a hindrance to the use of " renewables". The Government has embarked on the development of small-scale hydropower generating stations in the hinterland to cater for local communities. The potential exists for the setting up of wind farms and the use of sugarcane bagasse and rice biomass cogeneration systems. Solar power generation is another renewable source especially for small communities. There is the need to promote wind/solar-generating systems with diesel backup systems to cater for the larger communities outside of the urban areas. In order to promote the use of renewable technologies, there will have to be adequate human and institutional capacities, assessment of the potential of the renewables and the investments required to address the acquisition of the technologies.

There is the need to access coastal adaptation technologies, which are in use or have been demonstrated, to identify adaptation technology needs, examine how these technologies are developed and transferred and to seek funding for the transfer of these technologies.

8.4.2.5 Agriculture

The major crops are sugar and rice and these are important to the economy of Guyana. Adaptation to climate change will require changes in genetic stocks, improved and efficient irrigation practices, improved nutrient and water use efficiency and skillful risk management and production management practices. Mitigation measures can include carbon sequestration in soils, manure conversion to methane fuel, increased feed efficiency and reducing methane emissions from rice paddies. The mitigation measures should form part of a policy document on addressing emissions of greenhouse gases in the sector. The policy can then be implemented by way of incentives, regulations and facilitation of technology transfer. There is also the need to examine the impact of climate change on the sugar and rice industries with a view towards identifying the technological requirements for preserving these industries.

8.4.2.6 Forestry

Guyana's forest resource is already being sustainably used. However, there are actions, which can be taken to mitigate climate change and to adapt to the impacts of climate change. There is the need to examine the best means to promote climate mitigation technologies, including carbon sequestration in forest soils, and to determine, by way of collaboration with regional and international institutions, how to access, assess and obtain financial assistance for transfer of technologies.

8.4.2.7 Coastal Adaptation Technologies

Guyana's coast is low-lying and ninety percent of the population resides in the coast. The major agricultural crops are grown here and the commercial and industrial sectors are mostly located in the coastal belt.

8.4.2.8 Solid Waste Management and Waste Water Treatment

Methane is emitted from solid waste and wastewater through anaerobic decomposition and, together, they contribute about 20% of human-induced methane emissions. These emissions can be lowered by reducing waste generation (source reduction), diverting waste away from disposal sites (composting, recycling or incineration), recovering methane from waste and preventing waste decomposition in an anaerobic environment.

There is the need to identify the most effective mitigation activities and to accelerate the use of technologies, which are already in use in Guyana. Government will have to play a dominant role in technology transfer in this sector. The municipalities, the regional administrations and local communities will have to participate because the private sector may not see waste management as good business. However, appropriate policy and regulatory frameworks and incentives can motivate private sector involvement.

8.4.2.9 Human Health

Reducing the health impacts of climate change will require the reduction of exposure of local populations to climate change and its environmental and social consequences, reduction of the vulnerability of local populations to this exposure, and improved care and treatment for those whose health is adversely affected.

8.5 CONCLUSIONS

Guyana requires substantial financial and technical assistance in order to fully implement the Convention. The assistance ranges from capacity building and institutional strengthening to investment projects in the various sectors. Capacity building needs to be addressed at all levels of the socio-economic infrastructure: government (national and local), NGOs, private sector and community. Training will be necessary since the human resource base is very limited. Capacity building should also address the networking of the groups and linkages with regional and international scientific, professional and private enterprise groups in order to foster access to and assessment of information related to technology transfer.

Investment projects are needed in all the sectors, which have been identified in this document. Feasibility studies and project finance sourcing (by developed Country Partners) will be prerequisites for attracting international assistance for these projects. The government is prepared to take actions to remove local barriers to investment in climate-friendly technologies and will facilitate private sector and investors meetings and other actions in order to promote direct involvement of the private sector in transfer of technology projects.

9.0 SYSTEMIC OBSERVATION AND RESEARCH

MONITORING AND UNDERSTANDING
CLIMATE CHANGE AND IMPACTS

(CHAPTER NINE)

Anthropogenic Climate Change and its impacts can affect all sectors of socio-economic development in Guyana. It is therefore essential that the people of Guyana be fully prepared to respond to the adverse impacts. This will require actions to be undertaken to observe the effects of global warming and to conduct studies into the possible future impacts and response mechanisms. The education system must be involved in acquainting students with the effects of global warming and the issues that are being addressed at the national and international levels. An aggressive public awareness programme and training from the university levels down to the primary school level and at the community level will be necessary if Guyanese are to cooperate in responding to the adverse impacts of climate change.

9.0 SYSTEMIC OBSERVATION AND RESEARCH

CHAPTER 9

SYSTEMATIC OBSERVATION AND RESEARCH

To detect climate change, long periods (over 100 years) of reliable weather data have to be available for a network of locations which can indicate the regional variations in the climate. A relatively long period of impact monitoring is also required if accurate deductions, on the impacts, are to be made. Research is needed in order to analyse the records and to make projections into the future and on the details of the response mechanisms which will be required in order to adapt to and mitigate climate change.

A wireless weather station

9.0 SYSTEMIC OBSERVATION AND RESEARCH

9.1 INTRODUCTION

In Guyana, weather observations started since the 1800s. However, the records are not continuous due to discontinuities caused by temporary closure of stations, missing data and equipment failure. The transformation of the database from the old hardcopy format to a computerised one is proceeding but at a very slow pace due to the weakness of the human and technological resource bases. Sector -specific data collection is being done but not as a collective effort to effect analyses for detection of impact signals. Research into climate change and related issues are not currently being done in Guyana. However, the Government has been building a human resource base by ensuring that Guyanese participate in training workshops and courses whenever these are available.

9.2 DATA COLLECTION AND SYSTEMATIC OBSERVATION

The Hydrometeorological Service of the Ministry of Agriculture maintains a network of climatological stations in Guyana. At present, the network consists of eight synoptic stations located on the coast, in the savannahs and in the rainforest regions. In addition, there are ninety rainfall stations located around the country. The Guyana Sugar Corporation operates seventy-three rainfall stations and six climatological stations on the coast in the sugar estates. Linden Mining Company assists this Service with human resource at a climatological station in the inland region.

There are fifteen surface water hydrological, one A-sand aquifer and two shallow wells stations being maintained in Guyana. These are all owned by the Hydrometeorological Service. The efficient operation of the Networks are hindered mainly by inadequate staff to do timely maintenance.

Under the CPACC project, two tide guages have been installed at the mouth of two large rivers. These are located at Parika on the Essequibo River and Rosignol on the Berbice River. Sea levels and climatological data are transmitted to a regional centre at the University of the West Indies in Trinidad, which is quality checked and then posted on the Internet.

The Hydrometeorological Service maintains a hydrological database and a climatological database using HYDATA 3.0 and CLICOM Version 3.1 softwares. These softwares were made available under the Voluntary Cooperation Programme of the World Meteorological Organization. There are quite a number of years for which records are not processed because of a lack of human resources and equipment (and training) for digitizing chart data.

9.3 RESEARCH INSTITUTIONS

These are: -

- Hydrometeorological Service
- University of Guyana
- National Agriculture Research Institute
- Institute of Applied Science and Technology
- Guyana Natural Resources Agency
- IWOKRAMA Rainforest Project
- Guyana Rice Development Board.
- TROPENBOS

While all of these institutions are capable of being involved in research in climate change, only the Hydrometeorological Service has been addressing research into detecting climate change. IWOKRAMA and TROPENBOS have been working on carbon changes in the forestry sector. There is the need for a coordinated approach towards addressing detection of climate change and the impacts resulting from global warming.

9.4 DATA COLLECTION NEEDS

For the Hydrometeorological Service to address systematic observation, it will require substantial inputs in the following areas:

9.4.1 Equipment

Modern observing equipment needs to be deployed within the networks with capability for real-time monitoring, dissemination and processing of data. This is likely to be strengthened somewhat through the World Bank El Nino Emergency Assistance Project, which will provide several sets of automatic equipment to improve data collection in some areas. The equipment needs include sensors for gaseous emissions, transmission tools and computerized processing systems.

9.4.2 Training

The staff requires training in GIS, computer processing, use of satellite data (such as LANDSAT and SPOT imageries and TOPEX-Poseidon/Jason 1 for Sea Level monitoring) and data analyses and interpretation.

9.4.3 Field Observations

The networks need to be revised and extended to satisfy the requirements under the World Climate Programme.

9.5 IMPACT OBSERVATIONS BY SECTOR AGENCIES

All the sectors will require training and equipment to carry out routine impact observing. The human resources required to do these tasks will also have to be recruited. Data collection will also be required to conduct studies into baseline emissions and emission conversion factors.

9.6 RESEARCH NEEDS

The needs are primarily to address detection and prediction of changes in the climate; and to detect and predict the impacts and responses to climate change.

9.6.1 Climate Change Detection and Prediction

- Downscaling data from GCMs for modelling of climate and climate scenarios in Guyana.
- Analysing data collected in Guyana to detect signals of climate variability and change.
- Predicting regional shifts, in climate, within Guyana and its Exclusive Economic Zone.
- Predicting changes in the sea surface temperature, etc. of the coastal waters of Guyana.
- Shoreline changes and erosion due to sea level rise.
- Studies in extreme weather events, including storm surges.

9.6.2 Impacts Detection And Responses Prediction

- Vulnerabulity and adaptation of sugar and rice to different climate scenarios.
- Transport of pesticides and agrochemicals in the soil.
- Efficiency of the recharge of Guyana's aquifers and the influence of changing rainfall patterns on ground water availability.
- Efficiency of energy production from biomass.
- Efficiency of energy use in the transport sector.
- Lowering of GHG emissions in all sectors.
- Emissions baseline studies in the major sectors.
- Emission conversion factors in energy, agriculture and forestry sectors.

- Impacts of climate change on major crops and on animal production.
- Effects of climate change on socio-economic development.
- Studies into the impact of climate change on human settlements and Impact of climate change on water resources.
- Studies into the impact of climate change on health of ecosystems.

9.7 DATA STORAGE

There is the need for a central data bank for storage of all climate and climate change data. The formation of a climate change information centre will allow for this to happen. It will require equipment, trained personnel and office space.

9.8 CONCLUSION

The major need is for equipment, staff and limited area computer models for climate change prediction and for monitoring and detecting impacts of climate change. The capacity of sector agencies will require to be strengthened.

10.0 EDUCATION, PUBLIC AWARENESS AND TRAINING

CHAPTER 10

EDUCATION, PUBLIC AWARENESS AND TRAINING

The impacts of climate will affect socio-economic development. Responses may not be appreciated or understood by those who shall be affected. This will not allow for political stability at a time when all must cooperate to effect responses to vulnerable regions or sectors. Education, public awareness and training will be essential tools for avoiding future chaos.

10.0 EDUCATION, PUBLIC AWARENESS AND TRAINING

10.1 THE NEED FOR EDUCATION AND PUBLIC AWARENESS

For environmental conservation to succeed, the public must understand their role and be given the relevant skills so that they can effectively participate. In fact, it was agreed at United Nations Conference on Environment and Development that education is critical to promoting sustainable development and for improving the capacity of the population to address and deal with environment and development issues (UNCED, 1992).

In Guyana, it has been acknowledged that environmental awareness of the Guyanese public is low, and hence fosters environmental degradation. Although there are environmental awareness programmes offered by a number of institutions, these are not done in a coordinated form (National Environmental Education and Public Awareness Strategy, 1999).

The Environmental Protection Act of 1996 gives the Environmental Protection Agency of Guyana (EPA) an environmental awareness mandate. As such, in 1999, after a period of consultations, the EPA drafted a National Environmental Education and Public Awareness Strategy (NEEPAS, 1999). The goal of the strategy is to enhance the public consciousness with respect to the environment, and to encourage behavioural changes conducive to environmental management and protection. (NEEPAS, 1999).

Hence, for the adaptation and mitigation measures with respect to climate variability to be effectively implemented in Guyana, education and public awareness must play a critical role. This education and public awareness must be aimed at the different target groups in all of the relevant sectors, as well as the general public.

10.2 RELEVANT SECTORS

The relevant sectors to be targeted are those which have to implement mitigation measures, and those which have to adapt to climate change. These are:

- Energy
- Industry
- Agriculture
- Waste Management
- Forestry and Land Use
- Fisheries
- Human Settlements
- Human Health
- Water Resources
- Tourism
- Animal Health (including the health of wildlife)

Hence, for each sector, education and public awareness must be interwoven with the adaptation and mitigation measures. In fact, throughout this document, in the mitigation sections, there are clear outlines of the education and public awareness issues, which need to be addressed for the mitigation and adaptation measures to be enforceable.

10.3 TRAINING NEEDS

Knowledge of data collection, manipulation and interpretation are essential to the understanding of climate change and its implications for Guyana. In addition, training is imperative to the successful implementation of the adaptation and mitigation measures in Guyana. Specific areas in which training is required are:-

- Monitoring of climate change and its implications, e.g. erosion, health changes, forest loss, alteration and conversion of land uses.

- Use, interpretation and application of predictive computer models for climate change.
- Assessment of the vulnerability of various resources to climate change.
- Use of GIS in data analysis and presentation
- Information technology
- Data Management
- Use and maintenance of alternative sources of energy, such as solar power.
- Cultivation and harvesting practices in the use of hybrids of crops able to withstand the predicted climate changes.
- Construction and management of managed sanitary landfills.
- IPCC methodology for calculations and estimations of greenhouse gas emissions.
- Establishment of emissions baselines for each sector.
- Development of emission factors.

10.4 STRATEGY FOR IMPLEMENTING EDUCATION, PUBLIC AWARENESS AND TRAINING

Implementation of this strategy for education, public awareness and training with respect to climate change will seek:

- to enhance the public awareness of climate change and its associated implications for Guyana
- to encourage active participation in mitigation and adaptation measures
- to encourage integration of climate change issues into future developmental projects/actions/decisions
- to strengthen the capacity of agencies to monitor and evaluate climate change and its impacts.

10.4.1 The NEEPAS (1999) Strategy

In summary, the NEEPAS (1999) identifies the target groups and the major environmental issues to be addressed; the aims and activities associated with providing environmental education and public awareness for the various groups; and the time frames for implementation of the strategy.

The major target groups to be addressed by the NEEPAS (1999) are:

- Children and youth
- Teachers and Teacher's Unions
- Policy and Decision makers
- Elderly and the Disabled
- Consumers
- Religious Organisations
- Private Sector
- Resource Users
- Media
- General Public
- Scientific and Academic Community
- Religious Organizations

The major environmental issues to be addressed by the programmes within the NEEPAS (1999) are:

- Solid and Liquid Waste Management
- Water, Land and Air Pollution
- The Physical Environment and Human Health
- Consumerism
- Human Settlements
- Coastal Zone Management
- National Parks, Protected areas

- Forestry and Biodiversity

10.4.2 NEEPAS and Climate Change

Although climate change is not clearly identified as one of the major environmental education issues to be addressed by the NEEPAS (1999), it is likely to be partially addressed since it is related to all of the other environmental issues identified (in the NEEPAS). In addition, the target group for the Climate Change strategy is the same as indicated for the NEEPAS (1999). Hence, in order to reduce duplication, to promote coordination and to effectively utilise the human resources, **the EPA should include climate change as one of the major environmental issues to be addressed by the NEEPAS (1999).** However, there are a number of aspects to include:

- Climate education issues should be included when undertaking the curriculum audit at the primary and secondary school levels
- Climate courses must be available to all the degree programmes on the University of Guyana campus and on the Berbice campus, which is in operation.
- Fishermen should be included under the farmers/miners/loggers target group
- Tradesmen/ technicians should be included as a target group
- Under the scientific and academic community, the health community must be included. In addition, another aim should be to encourage them to undertake research in order to better understand climate change and its implications
- Target groups in the relevant sectors mentioned earlier, i.e. energy, industry, agri-culture, etc., should be subjected to education and public awareness, as well as involved in facilitating education and public awareness programmes with respect to climate change
- NCC members should be involved in facilitating education and public awareness programmes with respect to climate variability

Upon infusion of climate education into the NEEPAS (1999), as indicated above, it will be addressed by use of:

- the school system, both formal and non-formal
- in- and pre-service professional and occupational training
- community and non-formal education
- the mass media
- workshops, conferences and round table discussions

There is a proposal to establish a Climate Unit in the EPA. Upon the establishment of the Climate Unit, it is recommended for membership of the National Environmental Education Advisory Committee to advise on issues/programmes/plans related to climate. In addition, the Climate Unit should be facilitator in education and public awareness programmes for the various target groups. However, co-ordination of the climate education and public awareness programmes is expected be the task of the Education, Information and Training Division of the EPA.

It may be considered ideal to use the `train-the-trainers' approach in order to propagate the knowledge and skills (obtained from the training) in Guyana. Workshops, with the inclusion of practical or `hands on' sessions, are an effective method for providing the training required.

The Climate Unit should be primarily exposed to the training identified earlier, specifically the first five (5) areas. With regards to the last four (4) areas, the various agencies with the relevant sectors should be targeted. The Climate Unit must be primarily responsible for co-ordination of all training identified.

10.0 EDUCATION, PUBLIC AWARENESS AND TRAINING

In Guyana, there are difficulties with efficient collection, organisation, co-ordination and dissemination of data and information. In an effort to address this, there should be:

- The establishment of a section under the Climate Unit that will function as a National Climate Information Centre.
- The establishment of a network and networking between the relevant sectors and organisations for climate data collection, sharing, use and dissemination.

10.5 CONCLUSION

Education and Public Awareness are basic necessities for ensuring that response measures are understood and appreciated. This will allow for the public's support whenever responses are being implemented. It will require that the education system and the media agencies be capable of playing a fundamental role of sensitizing Guyanese to the vulnerability of the country and the need for particular response measures in the various regions and localities.

CHAPTER 11

11.0 CONCLUSIONS

This Initial National Communication under the UNFCCC reflects the first cooperative effort, in Guyana, to address issues related to Climate Change. It is also a reflection of the commitment of the Government and People of Guyana to honour our obligations towards the protection of the environment and to promote sustainable development.

It will not be easy for Guyana to take actions to mitigate climate change and adapt to the impacts of climate change while, at the same time, the country has to deal with the current pressing issues which confront the people in Guyana. However, with international assistance, the Government and the people of Guyana will work towards playing a meaningful role in addressing “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” - UNFCCC Article (2).

Calculation of baseline emissions, implementation of renewable energy programmes, technology transfer and capacity building are seen as priority actions to enable Guyana to address its obligations under the convention.

This Initial Communication recognized an inadequacy, which very likely, shall prevent Guyana from effectively reducing greenhouse gas emissions and respond to vulnerabilities while at the same time ensuring “that food production is not threatened and economic development to proceed in a sustainable manner “(UNFCCC Article 2). **The inadequacy is the insufficient capacity and institutional strength to act now.** Guyana is slowly moving out of an economic depression which lasted over three decades and its Government is striving to set up the institutional basis for ensuring that developmental programmes are implemented efficiently and effectively. In order to execute the Climate Change Action Plan (which is a supplement to this Initial Communication), the Government (including Local Government), the private sector, the local communities and other NGOs will have to build a capacity to coordinate, execute and sustain the programmes which will be required to address adaptation, monitoring and research issues. Training will be essential. Workshops, seminars, specialized short-period training and post-graduate training will be the tools for building a well trained human resource pool from which the Action Plan can be effected.

Guyana stands ready to do its part to ensure that the objective of the UNFCCC is realised.

Appendix 3.A

(i) **Selected Economic Indicators**

(ii) **Forestry Productions by Category**

(iii) **Livestock Population by Category**

SELECTED ECONOMIC INDICATORS - GUYANA

ITEM	UNIT	1990	1991	1992	1993	1994
Population (end of year)	000	750,648	719,074	738,965	746,949	763,687
Per Capita GDP	US$	528	485	506	531	612
GDP at current market prices	G$M	15,665	38,966	46,734	59,124	75,412
GDP at factor cost	G$M	3319	3519	3792	4104	4452
Breakdown (as % of total)	%					
Agriculture	%	23.6	25.0	28.9	28.3	29.2
Construction	%	7.4	7.1	6.7	6.5	7.1
Services	%	48.4	45.4	42.6	40.7	39.6
Manufacturing	%	11.1	11.6	12.9	12.3	12.0
Mining & Quarrying	%	9.5	10.8	8.9	12.2	12.0
GDP annual growth rate	%	-4.7	6.0	7.8	8.3	8.5
Small Savings Rate	%	27.50	26.18	16.58	9.46	11.20
Prime lending Rate	%	31.00	33.50	25.90	17.45	19.89
Visible trade balance	US$M	-42.8	-40.7	-51.0	-69.8	-40.6
Balance of payments	US$M	-193.7	-66.0	-39.3	-49.7	-63.9
Inflation rate	%	118.0	70.3	14.2	7.7	16.1
Visitor's arrival	000	74.5	62.9	94.9	107.3	112.8
Exchange Rate (average)	G$/US$	39.53	111.80	125.00	126.82	138.23
Forestry production[1]	Cubic meters	200,367	194,926	221,800	312,586	477,383
Total forest land area	Million hectares	16.45	16.45	16.45	16.45	16.45
Sugar production	tonnes	129,722	162,484	247,010	246,528	256,670
Rice production	tonnes	93,444	156,794	168,274	210,236	233,435
Livestock population[2]		15,564,534	15,575,032	15,508,530	15,515,333	15,493,660

1 See table on page 249 for breakdown on the various categories of wood.

2 See table on page 249 for breakdown on the various types of Livestock.

FORESTRY PRODUCTION BY CATEGORY (000'M^3)

YEAR	LOGS	ROUNDWOOD	SPLITWOOD	CHAINSAW LOGS	CHARCOAL	FIREWOOD	TOTAL
1990	123.02	9.873	1.185	35.37	4.162	26.757	200.367
1991	128.814	7.358	1.829	33.012	5.272	18.641	194.926
1992	139.451	14.628	1.473	42.44	6.429	17.379	221.8
1993	217.059	14.944	2.342	44.095	10.711	23.435	312.586
1994	376.75	14.371	2.792	47.16	12.875	23.435	477.383

Source: Guyana Forestry Commission

LIVESTOCK POPULATION BY CATEGORY

YEAR	CATTLE	SHEEP	GOATS	PIGS	HORSES	DONKEYS	CHICKENS	TOTAL
1990	279,534	130,000	77,000	75,000	2,000	1,000	15,000,000	**15,564,534**
1991	285,032	130,000	77,000	80,000	2,000	1,000	15,000,000	**15,575,032**
1992	260,530	130,000	79,000	36,000	2,000	1,000	15,000,000	**15,508,530**
1993	253,333	130,000	79,000	50,000	2,000	1,000	15,000,000	**15,515,333**
1994	227,099	130,000	79,000	50,000	2,000	1,000	15,000,000	**15,493,660**

Sources: 1 Ministry of Fisheries, Crops & Other Livestock, Guyana

2 FAO Estimates (1994 Yearbook)

APPENDIX 4.A

Greenhouse Gas Emissions and Removals – Tables (1990-1998)

TABLE 4.A.1: SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1990.

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1198 (-23,777)**	**40**	**1**	**5**	**136**	**4**
1 Energy - Reference Approach	1198					
A Fuel Combustion		N.A.	N.A.	N.A.	N.A.	N.A.
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes, Food & Beverage						4
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		31	1	3	68	
5 Land Use Change and Forestry (a)	-23777	8		2	68	
6 Waste		1				
Memo Items: (b)						
International Bunkers, total	23					
Aviation	18					
Marine	4					
CO_2 Emissions from Biomass	N.A.					

Key: **1.** (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.

(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.2: SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES YEAR 1991.

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1218 (-24,619)**	**42**	**1**	**5**	**146**	**4**
1 Energy - Reference Approach	1218					
A Fuel Combustion		N.A.	N.A.	N.A.	N.A.	N.A.
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes, Food & Beverg.						4
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		33	1	3	78	
5 Land Use Change and Forestry (a)	-24619	8		2	68	
6 Waste		1				
Memo Items: (b)						
International Bunkers, total	23					
Aviation	19					
Marine	4					
CO_2 Emissions from Biomas	N.A.					

Key: 1. (NO) - not occurring
2. (NE) - Not estimates
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.3: SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1992.

SUMARRY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1266 (25,387)**	**46**	**1**	**6**	**155**	**6**
1 Energy - Reference Approach	1266					
A Fuel Combustion		N.A.	N.A.	N.A.	N.A.	N.A.
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes, Food & Beverg.						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		37	1	4	87	
5 Land Use Change and Forestry (a)	-25387	8		2	68	
6 Waste		1				
Memo Items: (b)						
International Bunkers, total	27					
Aviation	20					
Marine	7					
CO_2 Emissions from Biomas	N.A.					

Key: 1. (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.4: SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1993

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1320 (-26,066)**	**47**	**1**	**6**	**161**	**6**
1 Energy - Reference Approach	1320					
A Fuel Combustion		N.A.	N.A.	N.A.	N.A.	N.A.
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes, Food & Beverage						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		38	1	4	93	
5 Land Use Change and Forestry (a)	-26066	8		2	68	
6 Waste		1				
Memo Items: (b)						
International Bunkers, total	28					
Aviation	21					
Marine	7					
CO_2 Emissions from Biomass	N.A.					

Key: 1. (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.5: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1994.

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES						
	CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1446** (26,664)	**51**	**1**	**17**	**208**	**23**
1 All Energy	**1446**	**1**		**11**	**45**	**6**
A Fuel Combustion	1446	1		11	45	6
1 Energy Industry	602			3	9	
2 Industry(Manufacturing)	191			1	3	
3 Transport	203			2	22	4
4 Other Sectors (Comm./Resid.;Agri./ect.	450			6	10	1
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**16**
A Mineral Products (asphalt use on road)	NO	NO	NO	NO	NO	10
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		**41**	**1**	**4**	**95**	
A Enteric Fermentation		14				
B Manure Management		1				
C Rice Cultivation		22				
D Agricultural soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	67	
5 Land-Use Change and Forestry (a)	**-26664**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-29195					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Landfill		1				
Memo Items (b)						
(i) International Bunkers, total	**28**					
- Aviation	24					
- Marine	4					
(ii) Biomass Emissions	**1200**					

Key: 1. (NO) - Not occurring
2. (NE) - Not estimated
3. (NA) – Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.6: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1995

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES						
	CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1469 (-27,459)**	**53**	**1**	**18**	**210**	**12**
1 All Energy	**1469**	**1**		**11**	**44**	**6**
A Fuel Combustion	1469	1		11	44	6
1 Energy Industry	561			2	9	
2 Industry(Manufacturing)	178			1	3	
3 Transport	204			2	22	4
4 Other Sectors (Comm./Resid.;Agri./ect.	526			7	11	2
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**6**
A Mineral Products	NO	NO	NO	NO	NO	N.A.
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		**44**	**1**	**4**	**98**	
A Enteric Fermentation		14				
B Manure Management		1				
C Rice Cultivation		25				
D Agricultural Soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	70	
5 Land-Use Change and Forestry (a)	**-27459**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-29990					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Landfill		1				
Memo Items (b)						
(i) International Bunkers, total	**30**					
- Aviation	26					
- Marine	4					
(ii) Biomass Emissions	**1157**					

Key: 1. (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown the table, may not represent the actual summing of values in the sub-headings of the table

TABLE 4.A.7: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1996.

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES						
	CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1538 (28,423)**	**57**	**2**	**18**	**215**	**13**
1 All Energy	**1538**	**1**		**12**	**48**	**7**
A Fuel Combustion	1538	1		12	48	7
1 Energy Industry	587			3	10	1
2 Industry(Manufacturing)	202			1	4	
3 Transport	253			2	24	5
4 Other Sectors (Comm./Resid.;Agri./ect.	496			8	10	2
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**7**
A Mineral Products	NO	NO	NO	NO	NO	N.A.
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						7
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		**50**	**1**	**4**	**99**	
A Enteric Fermentation		18				
B Manure Management		1				
C Rice Cultivation		27				
D Agricultural soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	71	
5 Land-Use Change and Forestry (a)	**-28423**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-30954					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Solid Waste Disposal		1				
Memo Items (b)						
(i) International Bunkers, total	**28**					
- Aviation	23					
- Marine	5					
(ii) Biomass Emissions	**1270**					

Key: 1. (NO) -not occurring
2. (NE) - Not estimated
3. (NA) – data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown the table, may not represent the actual summing of values in the sub-headings of the table

TABLE 4.A.8: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1997

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES						
	CO_2	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1663 (-29,259)**	**57**	**2**	**18**	**216**	**13**
1 All Energy	**1663**	**1**		**12**	**49**	**7**
A Fuel Combustion	1663	**1**		12	49	7
1 Energy Industry	713			3	9	1
2 Industry(Manufacturing)	187			1	4	
3 Transport	257			2	25	5
4 Other Sectors (Comm./Resid.;Agri./ect.	505			6	10	2
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**6**
A Mineral Products	NO	NO	NO	NO	NO	N.A.
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	NE.	NE.	N.E.
4 Agriculture		**48**	**1**	**4**	**99**	
A Enteric Fermentation		15				
B Manure Management		1				
C Rice Cultivation		27				
D Agricultural Soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	71	
5 Land-Use Change and Forestry (a)	**-29259**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-31788					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Landfill		1				
Memo Items (b)						
(i) International Bunkers, total	**31**					
- Aviation	22					
- Marine	9					
(ii) Biomass Emissions	**1248**					

Key: 1. (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table.

TABLE 4.A.9: SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES, YEAR 1998

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**CO_2**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**
Total National Emissions and (Removals)	**1749 (-31,034)**	**56**	**1**	**18**	**214**	**13**
1 All Energy	**1749**	**1**		**12**	**50**	**7**
A Fuel Combustion	1749	1		12	50	7
1 Energy Industry	742			3	9	1
2 Industry(Manufacturing)	264			1	4	
3 Transport	296			3	27	5
4 Other Sectors (Comm./Resid.;Agri./ect.	447			6	9	1
B Fugitive Emissions	Nil	Nil	Nil	Nil	Nil	
2 Industrial Processes	**NO**	**NO**	**NO**	**NO**	**NO**	**6**
A Mineral Products	NO	NO	NO	NO	NO	N.A.
B Chemical Industry	NO	NO	NO	NO	NO	
C Metal Production	NO	NO	NO	NO	NO	
D Beverages and food production						6
3 Solvent and Other Product Use	N.E.	N.E.	N.E.	N.E.	N.E.	N.E.
4 Agriculture		**46**	**1**	**4**	**96**	
A Enteric Fermentation		15				
B Manure Management		1				
C Rice Cultivation		26				
D Agricultural Soils			1			
E Prescribed Burning of Savannah		1			28	
F Field Burning of Agri. Residues		3		4	68	
5 Land-Use Change and Forestry (a)	**-31034**	**8**		**2**	**68**	
A Changes in Forest & Woody Biomass	-33,565					
B Forest and Grassland Conversion	2531	8		2	68	
6 Waste		**1**				
A Landfill		1				
Memo Items (b)						
(i) International Bunkers, total	**21**					
- Aviation	14					
- Marine	7					
(ii) Biomass Emissions	**1199**					

Key: 1. (NO) - not occurring
2. (NE) - Not estimated
3. (N.A.) - Data not available

Note: (a) - Emissions value indicated is the net of emissions and removals.
(b) - Not included in national emissions and removals.
(c) - Because the IPCC software rounds off values, the "Total National Emissions", shown in the table, may not represent the actual summing of values in the sub-headings of the table

APPENDIX 4.B

Uncertainty Tables

Table 4.B.1: Notation key for overview table.

NOTATION KEY FOR OVERVIEW TABLE							
Estimates		**Quality**		**Documentation**		**Disaggregation**	
Code	*Meaning*	*Code*	*Meaning*	*Code*	*Meaning*	*Code*	*Meaning*
PART	Partly estimated	**H**	High confidence in estimation	**H**	High (all background information included)	**1**	Total emissions estimated
ALL	Full estimate of all possible sources	**M**	Medium confidence in estimation	**M**	Medium (some background information included)	**2**	Sectoral split
NE	Not estimated	**L**	Low confidence in estimation	**L**	Low (only emission estimates included)	**3**	Sub-sectoral split
IE	Estimated but included elsewhere						
NO	Not occurring						
NA	Not applicable						
E	Estimate						
Q	Quality						

Table 4.B.2: Overview Table for National Greenhouse Gas Inventories.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O		NO_X		CO		NMVOC		Documentation	Disaggregation	Footnotes
	E	Q	E	Q	E	Q	E	Q	E	Q	E	Q			
TOTAL NATIONAL EMISSIONS AND REMOVALS															
Energy															
A- Fuel Combustion Activities															
Reference Approach	All	H											M	1	
Sectoral Approach	All	M	All	M	All	M	All	M	All	M	All	M	M	3	
1– Energy Industries	All	M	All	M	All	M	All	M	All	M	All	M	M	1	
2 – Manufacturing Industries and Construction	All	M	All	M	All	M	All	M	All	M	All	M	M	1	
3 – Transport	All	M	All	M	All	M	All	M	All	M	All	M	M	3	
4 – Other Sectors	All	M	All	M	All	M	All	M	All	M	All	M	M	3	
B – Fugitive Emissions	NO														
Industrial Processes	**NO**		**NO**		**NO**		**NO**		**NO**		**All**	**M**	**M**	**3**	
A – Mineral Products	NO										All	M	M	3	
B – Chemical Industry											NO				
C – Metal Production											NO				
D– Other Production											All	M	M	3	
Production of Halocarbons etc.											NO				

Table 4.B.3: Overview Table for National Greenhouse Gas Inventories

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O		NO_X		CO		NMVOC		Documentation	Disaggregation	Footnotes
	E	Q	E	Q	E	Q	E	Q	E	Q	E	Q			
Solvent and Other Product Use	NE														
Agriculture			All	M									M	3	
A – Enteric Fermentation			All	M									M	1	
B – Manure Management			All	M									M	1	
C – Rice Cultivation			All	M									M	1	
D – Agricultural Soils			All	M									M	1	
E – Prescribed Burning of Savannas			All	L									M	1	
F – Field Burning of Agricultural Residues	PART	M	PART	M	PART	M	PART	M	PART	M	PART	M	M	1	(a)
Land-Use Change and Forestry													M	3	
A – Changes in Forests and other Woody biomass	All	L											M	1	
B – Forest and Grassland Conversion	All	L	All	L	All	L	All	L	All	L	All	L	M	1	
C – Abandonment of Managed Lands	NE														(b)

Footnotes:

1. (a) Only emissions from sugar cane and rice residues burn in the field was estimated. Emissions from other crops are considered insignificant.

(b) - No data available, however, this is considered negligible.

Table 4.B4: Overview Table for National Greenhouse Gas Inventories

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O		NO_X		CO		NMVOC		Documentation	Disaggregation	Footnotes
	E	Q	E	Q	E	Q	E	Q	E	Q	E	Q			
Waste															
A – Solid Waste Disposal on Land			All	M									M	1	
B – Waste Water Handling			NA												
C – Waste Incineration	NE														
Memo Items:															
International Bunkers															
Aviation	All	M											M	1	
Marine	All	M											M	1	
CO_2 Emissions from Biomass	All	M											M	3	

BIBLIOGRAPHY

3.0 NATIONAL CIRCUMSTANCES

Bleakley, D. D of Phil., 1957 Observations on the Geomorphology and recent geological history of the coastal plain of British Guiana. Geological survey of British Guiana, Summary No. 1 Pg.21

Bleakley, D. D of Phil., 1964 Geological survey of British Guiana Bulletin No. 34 Bauxites and laterites of British Guiana, Geological Survey Department, Georgetown, British Guiana, British Guiana Litographic Company Limited.

Brown, Carl 1976 Caribbean gravity field and plate tectonics, the Geological Society of America, Special paper 169, USA.

Bunce, E.T., Phillips, J.D., Chase, R.L., & Bowen, C.O. 1970, The Lesser Antilles arc and the eastern margin of the Caribbean Sea in Maxwell, A.E., The Sea Vol. 4, Part 2, New York, Inter-science Pg. 359-385.

Morgan, W.J., 1968 Rises, trenches, great faults and crustal blocks, Journal Geophysics research, Vol. 73 No. 6, Pg. 1959-1982.

Chase, R.L. & Bunce, ET. 1969 Underthrusting of the eastern margin of the Antilles by the floor of the western North Atlantic,and origin of the Barbados ridge, Jour. Geophysical research. Vol.74 No. 6 p. 1413-1420.

4.0 NATIONAL INVENTORY OF GREENHOUSE GASES

Houghton, J.T., L.G. Meira Filho, B. Lim,K. Tréanton, I. Mamaty, Y. Bonduki, D.J. Griggs and B.A. Callender (editors) ,1996. Intergovernmental Panel on Climate Change (IPCC): Greenhouse Gas Inventory Reporting Instructions. ***Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories***. Volumes 1, 2 and 3.

Singh, B. and A. El Fouladi,1999. ***A Simplified Step- by- Step Methodology for Calculating Greenhouse Gas Inventories using the IPCC Guidelines***. Training Manual , 160 p.

IPCC 1995 Guidelines for National Greenhouse Gas Inventories.

IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories.

5.0 VULNERABILITY AND ADAPTATION ASSESSMENT

Easterling, D. R., Horton, B., Jones, P. D., Petersen, T. C., Karl, T. R., Parker, D. E., Salinger, M. J., Vacheslav, R., Plummer, N., Jameson, P., and Folland, C. K. 1997. Maximum and minimum temperature trends for the Globe, Science 277: 364-367.

Falkland, A.C. 1992: *Small Tropical Islands*. International Hydrological Programme Humid Tropics Programme Series No. 2. UNESCO: Paris, France.

Hadley Centre model report, 1998. Climate change and its impacts.

http://www.meto.gov.uk/sec5/CR_div/Brochure98.

Huang, J.C.K. 1997. Climate change and integrated coastal management: a challenge for small island nations. *Ocean & Coastal Management*, 37: 95-107.

IPCC 1990. *Strategies for Adaption to Sea Level Rise*. IPCC Response Strategies Working Group. Ministry of Transport and Public Works, Ministry of Housing, Netherlands.

IPCC CZMS, 1992: A common methodology for assessing vulnerability to sea-level rise—second revision. In: *Global Climate Change and the Rising Challenge of the Sea.* Report of the Coastal Zone Management Subgroup, Response Strategies Working Group of the Intergovernmental Panel on Climate Change, Ministry of Transport, Public Works and Water Management, The Hague, The Netherlands, Appendix C, 27 pp.

IPCC, 1998: The Regional impacts of climate change. An assessment of Vulnerability [Watson, R.T., M.C Zinyouera, and R.H. Moss (eds). Cambridge University Press, United Kingdom and New York , NY, USA] - Nurse, L.A R.F Maclean, A.G. Swarez, Chapter 9. Small Island States, pp 336-354.

Jones, R. N., Hennessy, K. J., Page, C. M., Walsh, K. J. E., Whetton, P. H. 1999. An Analysis of the Effects of Kyoto Protocol on Pacific Island Countries. Part Two: Regional Climate Change Scenarios and Risk Assessment Methods. A Research Report prepared for the South Pacific regional Environment Programme, Apia, Samoa. CSIRO Atmospheric Research, Australia.

Khan, S. M. and Sturm, M.F. 1994 Assessment of the Vulnerability of coastal areas to sea level rise – Case study report on Guyana, CZM– Centre Publication No. 1, April 1994.
Leatherman, S.P. 1996. Shoreline stabilization approaches in response to sea level rise: US experience and implications for Pacific island and Asian nations. *Water, Air and Soil Pollution*, 92: 149-157.

Nicholls, R.J. and J. Branson (eds.), 1998: Enhancing coastal resilience—planning for an uncertain future. *The Geographical Journal*, 164(3), 255-343.

Nicholls, R.J. and Hoozemans, M.J. 1996. The Mediterranean: vulnerability to coastal implications of climate change. *Ocean & Coastal Management*, 31: 105-132.

Nicholls, R.J. and Leatherman, S.P. 1996. Adapting to sea-level rise. Relative sea-level trends to 2100 for the United States. *Coastal Management*, 24: 301-324.

Royer, F, B. Chauvin, P. Timbal, P. Araspin, and D. Grimal,, 1998 A GCM study of the impact of greenhouse gas increases on the frequency of occurrence of tropical cyclones. *Climatic Change*, 38, 307-343.

Simon, K. 1997. The Effect of the El Niño/La Niña and Southern Oscillation on South American Precipitation, M.Sc. Dissutations, Leading University, August 1997.

Singh,B. 1997a. Climate-related Global Changes in the Southern Caribbean: Trinidad and Tobago. *Global and Planetary Change.* Vol. 15 : 93-111

Singh B. 1997. Climate changes in the Greater and Southern Caribbean. *International Journal of Climatology.* Vol.17:1093-1114

Singh, B. and M. El Maayar (1998). Potential impacts of a greenhouse gas climate change scenarios on sugar cane yields in Trinidad, southern Caribbean. Tropical Agriculture Vol. 75 No. 3 :348-355.

6.0 ADAPTATION

Bijlsma, L. 1997. Climate change and the management of coastal resources. *Climate Research*, 9: 47-56.

Bijlsma, L., C.N. Ehler, R.J.T. Klein, S.M. Kulshrestha, R.F. McLean, N. Mimura, R.J.

Nicholls, L.A. Nurse, H. Pérez Nieto, E.Z. Stakhiv, R.K. Turner, and R.A. Warrick, 1996: Coastal zones and small islands. In: *Climate Change 1995—Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses* [Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds.)]. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 289-324.

Campbell, J.R. and Ericksen, N.J. 1990. Change, extreme events and natural hazards. In: Climate change impacts on New Zealand: Implications for the environment, economy and society. Ministry for the Environment, pp19-28.

Carter, T.R., M.L. Parry, S. Nishioka, and H. Harasawa (eds.), 1994: *Technical Guidelines for Assessing Climate Change Impacts and Adaptations.* Report of Working Group II of the Intergovernmental Panel on Climate

Charles, E. 1997. *A Future for Small States : Overcoming Vulnerability*. Commonwealth Secretariat, London, UK.

Gillie, R.D., 1997: Causes of Coastal Erosion in Pacific Island Nations. In Journal of Coastal Research Special issue - No 24, Island States at risk [Stephen P. Leatherman, Editor], pp. 174-204

Gilman, E.L. 1997. Community based and multiple purpose protected areas: a model to select and manage protected areas with lessons from the Pacific islands. *Coastal Management*, 25: 59-91.

Hales, S, Weinstein, P.and A. Woodward, 1997: Public health impacts of global climate change. *Reviews on Environmental Health,* 12(3), pp.191-199.

Hales, S, Weinstein, P., Souares, Y. and A. Woodward, 1999a: El Nino and the dynamics of vector-borne disease transmission. *Environmental Health Perspectives,* 107 (2), pp. 3-6.

Hay, J.E and Sem, G. 1999. A regional synthesis of national vulnerability and adaptation assessment, South Pacific Regional Environment Programme, Apia, Samoa.

Hay, J.E., Kaluwin, C. and N. Koop, 1995: Implications of climate change and sea level rise for small island nations of the South Pacific: A regional synthesis. *Weather and Climate,* 15,pp. 5-20.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4:1-23.

Huang, J.C.K. 1996. Climate change adaptation strategies: a challenge for small island nations. In J.B. Smith, *et al*. 1996. *Adapting to Climate Change : An International Perspective*. Springer-Verlag, New York, pp 311-321.

Huang, J.C.K. 1997. Climate change and integrated coastal management: a challenge for
IPCC 1990. *Strategies for Adaption to Sea Level Rise*. IPCC Response Strategies Working Group. Ministry of Transport and Public Works, Ministry of Housing, Netherlands.

IPCC CZMS, 1992: A common methodology for assessing vulnerability to sea-level rise—second revision. In: *Global Climate Change and the Rising Challenge of the Sea.* Report of the Coastal Zone Management Subgroup, Response Strategies Working Group of the Intergovernmental Panel on Climate Change, Ministry of Transport, Public Works and Water Management, The Hague, The Netherlands, Appendix C, 27 pp.

IPCC, 1998: The Regional impacts of climate change. An assessment of Vulnerability [Watson, R.T., M.C Zinyouera, and R.H. Moss (eds). Cambridge University Press, United Kingdom and New York , NY, USA] - Nurse, L.A R.F Maclean, A.G. Swarez, Chapter 9. Small Island States, pp 336-354.

Kaly, U., L. Briguglio, H. McLeod, S. Schmall, C. Pratt, R. Pal, 1999: *Environmental Vulnerability Index (EVI) to Summarise National Environmental Vulnerability Profiles.* Technical Report 275, South Pacific Applied Geoscience Commission, Suva, Fiji, vi+67 pp.

Kay, R.C. and J.E. Hay, 1993: A decision support approach to coastal vulnerability and resilience assessment: a tool for integrated coastal zone management. In: *Vulnerability Assessment to Sea-Level Rise and Coastal Zone Management* [McLean, R.F. and N. Mimura(eds.)]. Proceedings of the IPCC/WCC'93 Eastern Hemisphere workshop, Tsukuba, Japan, 3-6 August 1993, Department of Environment, Sport and Territories, Canberra, Australia, pp. 213-225.

Klein, R.J.T. and R.J. Nicholls, 1998: Coastal zones. In: *Handbook on Climate Change Impact Assessment and Adaptation Strategies* [Feenstra, J.F., I. Burton, J.B. Smith, and R.S.J. Tol (eds.)]. Version 2.0, United Nations Environment Programme and Institute for Environmental Studies, Vrije Universiteit, Nairobi, Kenya, and Amsterdam, The Netherlands, pp. 7.1-7.35.

Klein, R.J.T. and R.J. Nicholls, 1999: Assessment of coastal vulnerability to climate change. *Ambio*, 28(2), 182-187.

Leatherman, S.P. 1996. Shoreline stabilization approaches in response to sea level rise: US experience and implications for Pacific island and Asian nations. *Water, Air and Soil Pollution*, 92: 149-157.

Ludwig, D., Walker, B. and Holling, C.S. 1997. Sustainability, stability and resilience. Conservation Ecology 1(1):7. http://www.consecol.org/vol1/iss1/art7

Meehl, G.A. 1996. Vulnerability of freshwater resources to climate change in the tropical Pacific region. *Water, Air and Soil Pollution*, 92: 203-213.

Nicholls, R.J. and J. Branson (eds.), 1998: Enhancing coastal resilience—planning for an uncertain future. *The Geographical Journal*, 164(3), 255-343.

Nicholls, R.J. and Leatherman, S.P. 1996. Adapting to sea-level rise. Relative sea-level trends to 2100 for the United States. *Coastal Management*, 24: 301-324.

Nicholls, R.J. and Mimura, N. 1998. Regional issues raised by sea-level rise and their policy implications. *Climate Change*, 11: 5-18.

Nurse, L.A., R.F. McLean, and A.G. Suarez, 1998: Small Island States. In: *The Regional Impacts of Climate Change—An Assessment of Vulnerability* [Watson, R.T., M.C. Zinyowera, and R.H. Moss (eds.)]. Special Report of Working Group II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, pp. 331-354.

Rijsberman, F. 1996. Rapporteur's Statement. In J.B. Smith, *et al*. 1996. *Adapting to Climate Change : An International Perspective*. Springer-Verlag, New York, USA, pp. 279-282.

Royer, F, B. Chauvin, P. Timbal, P. Araspin, and D. Grimal,, 1998 A GCM study of the impact of greenhouse gas increases on the frequency of occurrence of tropical cyclones. *Climatic Change*, 38, 307-343.

Sem, G., Campbell, J.R., Hay, J. E., Mimura, N., Nishioka, S., Yamada, K., Ohno, E., and Serizawa, M. 1996. Coastal Vulnerability and Resilience in Tuvalu. Assessment of Climate Change Impacts and Adaptation, South Pacific Regional Environment Programme, Apia,

Samoa, Environment Agency of Japan, Overseas Environmental Cooperation Centre, Japan.
Singh,B. 1997a. Climate-related Global Changes in the Southern Caribbean: Trinidad and Tobago. *Global and Planetary Change.* Vol. 15 : 93-111

Singh B. 1997. Climate changes in the Greater and Southern Caribbean. *International Journal of Climatology.* Vol.17:1093-1114

Spalding, M.D. and A.M. grenfell, 1997, New estimates of global and regional coral reef areas. *Coral Reefs*, 16, 225-230.

Warrick, R.A., Kenny, G.J., Sims, G.C., Ye., W. and G. Sem, 1999: VANDACLIM: A training tool for climate change vulnerability and adaptation assessment. In C. Kaluwin and J.E. Hay, editors, *Climate Change and Sea Level Rise in the South Pacific Region.* Proceedings of the Third SPREP Meeting, New Caledonia, August, 1997. South Pacific Regional Environment Programme, Apia, Western Samoa, pp. 147-156.

West, J.J. & Dowlatabadi, H. 1999. On assessing the economic impacts of sea level rise on developing coasts. In T.E. Downing, A.A. Olsthoorn & R.S.J. Tol, editors, *Climate, Change and Risk*. Routledge, London, UK, pp. 205-220.

Wong, P.P. 1992. Impact of a sea leel rise on the coast of Singapore : preliminary observations. *Journal of Southeast Asian Earth Sciences*, 7 : 65-70.

Woodward, A., Hales, S. and P. Weinstein, 19??: Climate change and human health in the Asia Pacific region: who will be most vulnerable? *Climate Research, (in press).*
Wells, J. 1996. Composite vulnerability index: A preliminary report. Commonwealth Secretariat, London.

Wells, J. 1997. Composite vulnerability index: A revised report. Commonwealth Secretariat, London.

Yamada, K., P.D. Nunn, N. Mimura, S. Machida, and M. Yamamoto, 1995: Methodology for the assessment of vulnerability of South Pacific island countries to sea-level rise and climate change. *Journal of Global Environment Engineering*, 1(1), 101-125..

Yohe, G. *et al*. 1996. The economic costs of greenhouse-induced sea-level rise for developed property in the United States. *Climate Change*, 32: 387-410.

7.0 MITIGATION ANALYSIS

Millich, l.,1999.The role of methane in global warming: where might mitigation strategies be focused?. ***Global Environmental Change***. Vol. 9 No.3: 179-201.

Ramnathan, R.,1999.Selection of appropriate greenhouse gas mitigation options. ***Global Environmental Change***. Vol. 9 No.3: 203-210.

SINGH, B., J. BOIVIN, G. KIRKPATRICK, B. HOULE and B. HUM, 1994. The Surface Energy and Water Balance System (SEWBS): a computer-assisted approach to irrigation scheduling ***West Indian Journal of Engineering***. Vol. 17, No. 1, 29-45.

.SINGH, B., J. BOIVIN, G. KIRKPATRICK, B. HOULE, and B. HUM. 1995. Automatic Irrigation Scheduling System (AISSUM): Principles and Applications. ***Journal of Irrigation and Drainage Engineering***. Vol. 121, No. 1, 43-56.

Watson, R., M.C. Zinyowera, R.H. Moss and D.J. Dokken,1996. ***CLIMATE CHANGE 1995. Impacts, Adpatatations and Mitigation of Climate Change: Scientific-Technical analyses***. IPCC Second assessment Report. Cambridge University Press., London, 878p.